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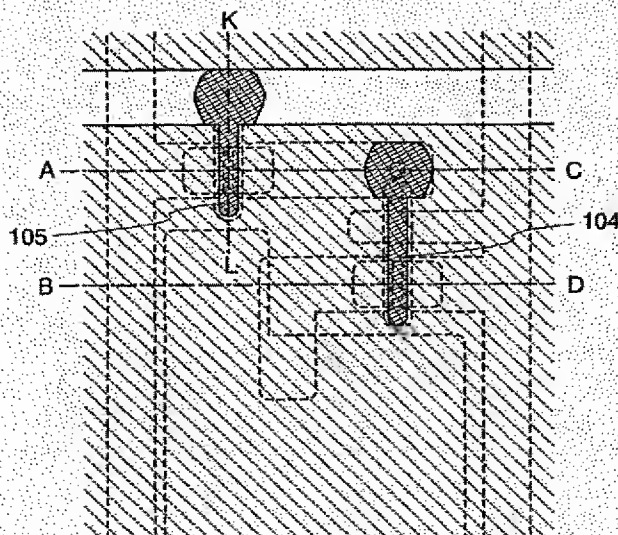
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(54) Title: THIN FILM TRANSISTOR AND DISPLAY DEVICE, AND METHOD FOR MANUFACTURING THEREOF



(57) Abstract: The present invention discloses a display device and a manufacturing method thereof by which a manufacturing process can be simplified. Further, the present invention discloses technique for manufacturing a pattern such as a wiring into a desired shape with good controllability. A method for forming a pattern for constituting the display device according to the present invention comprises the steps of forming a first region and a second region; discharging a composition containing a pattern formation material to a region across the second region and the first region; and flowing a part of the composition discharged to the first region into th

## DESCRIPTION

THIN FILM TRANSISTOR AND DISPLAY DEVICE, AND METHOD FOR  
MANUFACTURING THEREOF

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## TECHNICAL FIELD

The present invention relates to a method for forming a pattern, a thin film transistor, a method for manufacturing the same, a display device, a method for manufacturing the same, and a television device using the foregoing thin film transistor and display device.

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## BACKGROUND ART

A thin film transistor (hereinafter, TFT) and an electronic circuit using the TFT is manufactured by stacking various thin films such as a semiconductor, an insulator, or a conductor over a substrate, and forming appropriately a predetermined pattern by photolithography technique. The photolithography technique means technique of transferring a pattern such as a circuit made from a material that does not transmit light formed over a transparent plane surface referred to as a photomask to a substrate by utilizing light. The photolithography technique is widely used in a manufacturing process for a semiconductor integrated circuit and the like.

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25

In a manufacturing process using the conventional

photolithography technique, many processes such as exposing, developing, baking or exfoliating are required to handle a mask pattern formed by using a photosensitive organic resin material referred to as a photoresist. Therefore, the increase of the number of the photolithography processes inevitably leads to the increase of a manufacturing cost. In order to solve such problems, it has been tried to manufacture a TFT by a method with reduced number of the photolithography processes (Unexamined Patent Publication No. 11-251259).

10           However, the technique disclosed by Unexamined Patent Publication No. 11-251259 does not contribute to reduce drastically the number of processes, since a part of the photolithography processes performed at a plurality of times in a TFT manufacturing process is merely substituted by a printing process. A photolithography machine, which is used for transferring a mask pattern in the photolithography process, is a machine for transferring a pattern of 1 micron or less by means of same magnification projection exposure or reduced projection exposure. In principle, it is technically-difficult that a large substrate having a side of 1 meter or more is exposed at one time by the photolithography machine.

#### DISCLOSURE OF INVENTION

25           It is an object of the present invention to provide

technique by which the number of photolithography processes is reduced in a manufacturing process of a TFT, a display device using the TFT, and an electronic circuit using the TFT; a manufacturing process is simplified; and manufacture at low costs with good yields can be realized even if a large substrate having a side of one meter or more is used.

It is another object of the present invention to provide technique for forming a pattern such as a wiring that composes these display devices into a desired shape with good controllability.

As a display device according to the present invention, a light-emitting display device in which a light-emitting element including a medium containing an organic matter generating light emission referred to as electroluminescence (hereinafter, EL) or a mixture of the organic matter and an inorganic matter is interposed between a pair of electrodes is connected to TFT; and a liquid crystal display device using a liquid crystal element including a liquid crystal material as a display element are taken as examples.

A method for forming a pattern comprises the steps of forming a first region and a second region; discharging a composition containing a pattern formation material to a region across the second region and the first region; and flowing a part of the composition discharged to the first region into the second region; wherein wettability with respect to the

composition of the first region is lower than that of the second region.

A method for forming a pattern comprises the steps of forming selectively a mask to a subject formation region; forming a first region by using the mask; forming a second region by removing the mask; discharging a composition containing a pattern formation material to a region across the second region and the first region; and flowing a part of the composition discharged to the first region into the second region; wherein  
10 wettability with respect to the composition of the first region is lower than that of the second region.

A method for forming a pattern comprises the steps of forming selectively a photocatalytic substance to a subject formation region; forming a first region over the subject formation region and the photocatalytic substance; emitting  
15 light to the photocatalytic substance to form a second region; discharging a composition containing a pattern formation material to a region across the second region and the first region; and flowing a part of the composition discharged to the first region into the second region; wherein wettability with  
20 respect to the composition of the first region is lower than that of the second region.

A method for forming a pattern comprises the steps of forming a first region to a subject formation region; emitting  
25 light selectively to the first region to form a second region;

discharging a composition containing a pattern formation material to a region across the second region and the first region; and flowing a part of the composition discharged to the first region into the second region; wherein wettability with  
5 respect to the composition of the first region is lower than that of the second region.

A method for manufacturing a thin film transistor comprises the steps of forming a first region and a second region; discharging a composition containing a conductive  
10 material to a region across the second region and the first region; and flowing a part of the composition discharged to the first region into the second region to form an electrode layer; wherein wettability with respect to the composition of the first region is lower than that of the second region.

15 A method for manufacturing a thin film transistor comprises the steps of forming a first region and a second region; discharging a composition containing a conductive material to a region across the second region and the first region; flowing a part of the composition discharged to the  
20 first region into the second region to form an electrode layer; and discharging a conductive material to the second region to be in contact with the electrode layer to form a wiring layer; wherein wettability with respect to the composition of the first region is lower than that of the second region.

25 A method for forming a pattern comprising the steps of

forming selectively a photocatalytic substance to a subject formation region; forming a first region over the subject formation region and the photocatalytic substance; emitting light to the photocatalytic substance to form a second region; 5 discharging a composition containing a conductive material to a region across the second region and the first region; and flowing a part of the composition discharged to the first region into the second region to form an electrode layer; wherein wettability with respect to the composition of the first region 10 is lower than that of the second region.

A method for manufacturing a thin film transistor comprising the steps of forming a first region and a second region; discharging a composition containing a mask formation material to a region across the second region and the first 15 region; flowing a part of the composition containing the mask formation material discharged to the first region into the second region to form a mask; removing a part of the first region by using the mask to form a fourth region and to form a third region by removing the mask; a composition containing a 20 conductive material to a region across the fourth region and the third region; flowing a composition containing the conductive material in the third region into the fourth region to form a first electrode layer and a second electrode layer; and flowing a part of the composition discharged to the first 25 region into the second region; wherein wettability with respect

to the composition containing the mask formation material of the first region is lower than that of the second composition, and wettability with respect to the conductive material of the third region is lower than that of the fourth region.

5           In the foregoing structures, a display device can be manufactured by forming the electrode layer as a gate electrode layer and forming the wiring layer as a gate wiring layer. Further, in the foregoing structure, a display device can be manufactured by forming each of the first electrode layer and  
10   the second electrode layer as a source electrode layer or a drain electrode layer.

          A thin film transistor comprises a wiring layer provided over an insulating surface having a first region and a second region; and an electrode layer being in contact with the wiring  
15   layer; wherein the wiring layer is provided to the second region, the electrode layer is provided to the first region, and wettability with respect to the electrode layer and the wiring layer of the first region is lower than that of the second region.

          A thin film transistor comprises a wiring layer provided  
20   over an insulating surface having a first region and a second region; and an electrode layer being in contact with the wiring layer; wherein the wiring layer is provided to the second region, the electrode layer is provided to the first region, wettability with respect to the electrode layer and the wiring layer of the  
25   first region is lower than that of the second region, and the



electrode layer has a smaller width and a thinner thickness than those of the wiring layer.

A display device comprises a gate wiring layer provided over an insulating surface having a first region and a second region; and a thin film transistor including a gate electrode layer being in contact with the gate wiring layer; wherein the gate wiring layer is provided to the second region, the gate electrode layer is provided to the first region, and wettability with respect to the gate electrode layer and the gate wiring layer of the first region is lower than that of the second region.

A display device comprises a gate wiring layer provided over an insulating surface having a first region and a second region; and a thin film transistor including a gate electrode layer being in contact with the gate wiring layer; wherein the gate wiring layer is provided to the second region, the gate electrode layer is provided to the first region, wettability with respect to the gate electrode layer and the gate wiring layer of the first region is lower than that of the second region, and the gate electrode layer has a smaller width and a thinner thickness than those of the gate wiring layer.

A television device comprises a display screen formed by a display device having a gate wiring layer provided over an insulating surface having a first region and a second region and a thin film transistor including a gate electrode layer being in contact with the gate wiring layer; wherein the gate

wiring layer is provided to the second region, the gate electrode layer is provided to the first region, and wettability with respect to the gate electrode layer and the gate wiring layer of the first region is lower than that of the second region.

5        A television device comprises a display screen formed by a display device having a gate wiring layer provided over an insulating surface having a first region and a second region and a thin film transistor including a gate electrode layer being in contact with the gate wiring layer; wherein the gate  
10 wiring layer is provided to the second region, the gate electrode layer is provided to the first region, wettability with respect to the gate electrode layer and the gate wiring layer of the first region is lower than that of the second region, and the gate electrode layer has a smaller width and a thinner  
15 thickness than those of the gate wiring layer.

In the foregoing structure, a first region can be formed by forming a substance including a fluorocarbon chain that is a substance having a fluoride. As the photocatalytic substance, titanium oxide can be used.

20        According to the present invention, a desired pattern can be formed with well controllability; and loss of material can be reduced, and costs can be reduced. Therefore, a display device having high performance and high reliability can be manufactured with good yields.

BRIEF DESCRIPTION OF DRAWINGS

FIGS. 1A to 1H are explanatory views for the present invention;

FIGS. 2A to 2H are explanatory views for the present  
5 invention;

FIG. 3 is an explanatory view for a method for manufacturing a display device according to the present invention;

FIG. 4 is an explanatory view for a method for  
10 manufacturing a display device according to the present invention;

FIG. 5 is an explanatory view for a method for manufacturing a display device according to the present invention;

FIG. 6 is an explanatory view for a method for  
15 manufacturing a display device according to the present invention;

FIG. 7 is an explanatory view for a method for manufacturing a display device according to the present  
20 invention;

FIG. 8 is an explanatory view for a method for manufacturing a display device according to the present invention;

FIG. 9 is an explanatory view for a method for  
25 manufacturing a display device according to the present

invention;

FIG. 10 is an explanatory view for a method for manufacturing a display device according to the present invention;

5        FIGS. 11A to 11C are explanatory views for a method for manufacturing a display device according to the present invention;

FIGS. 12A to 12C are explanatory views for a method for manufacturing a display device according to the present  
10    invention;

FIGS. 13A to 13C are explanatory views for a method for manufacturing a display device according to the present invention;

FIGS. 14A to 14C are explanatory views for a method for  
15    manufacturing a display device according to the present invention;

FIGS. 15A to 15C are explanatory views for a method for manufacturing a display device according to the present invention;

20        FIGS. 16A to 16C are explanatory views for a method for manufacturing a display device according to the present invention;

FIGS. 17A to 17C are explanatory views for a method for manufacturing a display device according to the present  
25    invention;

FIGS. 18A to 18C are explanatory views for a method for manufacturing a display device according to the present invention;

FIGS. 19A to 19C are cross-sectional views of a display  
5 device according to the present invention;

FIG. 20 shows an electronic device applied with the present invention;

FIGS. 21A to 21D show electronic devices applied with the present invention;

10 FIG. 22 is an explanatory cross-sectional view for a structure example of an EL display module according to the present invention;

FIG. 23 is an equivalent circuit diagram of a display panel explained with reference to FIG. 24;

15 FIG. 24 is an explanatory top view for a display panel according to the present invention;

FIG. 25 is an explanatory view for a circuit structure in the case that a scanning line side driver circuit is formed using a TFT in a display panel according to the present  
20 invention;

FIG. 26 is an explanatory view for a circuit structure in the case that a scanning line side driver circuit is formed by a TFT in a display panel according to the present invention (shift resistor circuit);

25 FIG. 27 is an explanatory view for a circuit structure

in the case that a scanning line side driver circuit is formed by a TFT in a display panel according to the present invention (buffer circuit);

FIG. 28 is an explanatory view for a structure of a droplet discharging device that can be applied to the present invention;

FIGS. 29A to 29C are top views of display devices according to the present invention;

FIGS. 30A and 30B are top views of display devices according to the present invention;

FIG. 31 is an explanatory view for a method for manufacturing a display device according to the present invention;

FIGS. 32A to 32F are explanatory circuit diagrams for structures of pixels that can be applied to EL display panels according to the present invention;

FIGS. 33A and 33B are explanatory top and cross-sectional views for a display panel according to the present invention;

FIG. 34 is an explanatory cross-sectional view for a structure example of an EL display module according to the present invention;

FIG. 35 is an explanatory cross-sectional view for a structure example of an liquid crystal display module according to the present invention;

FIGS. 36A to 36E are explanatory views for a method for manufacturing a display device according to the present

invention;

FIGS. 37A and 37B are explanatory views for a method for manufacturing a liquid crystal display device according to the present invention;

5        FIGS. 38A to 38D are explanatory views for the present invention;

FIG. 39 is an explanatory view for a liquid crystal droplet injecting method that can be applied to the present invention;

10        FIG. 40 shows a wiring manufactured according to the present invention;

FIGS. 41A and 41B show wirings manufactured according to comparative examples;

FIGS. 42A to 42C show a wiring manufactured according to the present invention;

15        FIGS. 43A to 43C show a wiring manufactured according to the present invention; and

FIGS. 44A to 44C show a wiring manufactured according to the present invention.

## 20    BEST MODE FOR CARRYING OUT THE INVENTION

### Embodiment 1

Although the present invention will be fully described by way of embodiments with reference to the accompanying drawings, it is to be understood that various changes and  
25    modifications will be apparent to those skilled in the art.

Therefore, unless otherwise such changes and modifications depart from the scope of the present invention hereinafter described, they should be construed as being included therein. Through the drawing of the embodiments, same components are  
5 denoted by same numerals, and will not be further explained.

FIG. 29A illustrates a top view for showing an example of a structure of a display panel according to the present invention. A pixel portion 2701 composed of pixels 2702 in a matrix configuration over a substrate 2700 having an insulating  
10 surface, a scanning line side input terminal 2703, and a signal line side input terminal 2704 are formed. The number of pixels may be set according to various specifications, for example,  $1024 \times 768 \times 3$  (RGB) for XGA,  $1600 \times 1200 \times 3$  (RGB) for UXGA, or  $1920 \times 1080 \times 3$  (RGB) in case of corresponding to full spec  
15 high vision.

The pixels 2702 are arranged in a matrix configuration by crossing scanning lines extended from the scanning line side input terminal 2703 and signal lines extended from the signal line side input terminal 2704. Each of the pixels 2702 is  
20 provided with a switching element and a pixel electrode that connects to the switching element. A typical example of the switching element is a thin film transistor (TFT). Each of the pixels can be independently controlled by signals input from the outside by connecting the scanning line to a gate electrode  
25 side of the TFT and connecting a source or a drain to the signal



lines.

As main components of a TFT, a semiconductor layer, a gate insulating layer, and a gate electrode layer can be used. A wiring layer connected to source and drain regions formed over  
5 the semiconductor layer is attached to the foregoing main components. As a structure of the TFT, a top gate structure composed sequentially of a substrate, a semiconductor layer, a gate insulating layer, and a gate electrode layer; or a bottom  
10 gate structure composed sequentially of a substrate, a gate electrode layer, a gate insulating layer, and a semiconductor layer are typically known. The present invention can use either of the structures.

As a material for forming the semiconductor layer, amorphous semiconductor (hereinafter, AS) by a vapor deposition  
15 method or a sputtering method, each of which uses a semiconductor material gas as typified by silane or germane; polycrystalline semiconductor that is formed by crystallizing the amorphous semiconductor using light energy or thermal energy; or semiamorphous semiconductor that may be referred to  
20 microcrystal (hereinafter, SAS) can be used.

The SAS has an intermediate structure between an amorphous structure and a crystalline structure (including a single crystal and a poly crystal). The semiamorphous semiconductor has a stable third state with respect to free  
25 energy, and a crystalline region having a short-range order and

lattice distortion. At least a part of the semiconductor includes crystal grains with grain diameters of from 0.5 to 20 nm. Raman spectrum originated by LO phonon peak is shifted to a lower wave number than  $520\text{ cm}^{-1}$ . By X-ray diffraction, 5 diffraction peaks (111), (220) that may be derived from a Si crystalline lattice are observed. Hydrogen or halogen of 1 atomic% or more is contained in the semiamorphous semiconductor as neutralizer for dangling bond. Such semiamorphous semiconductor is referred to as what is called micro crystal 10 semiconductor. A silicide gas is used to be carried out with glow discharge decomposition (plasma CVD). As the silicide gas,  $\text{Si}_2\text{H}_6$ ,  $\text{SiH}_2\text{Cl}_2$ ,  $\text{SiHCl}_3$ ,  $\text{SiCl}_4$ ,  $\text{SiF}_4$ , or the like in addition to  $\text{SiH}_4$  can be used. The silicide gas can be diluted by  $\text{H}_2$ , or the  $\text{H}_2$  and one or a plurality of rare gas elements selected from 15 the group consisting of He, Ar, Kr, and Ne. The dilution rate is in the range of from 2 to 1000 times. An applied voltage is in the range of from 0.1 to 133 Pa. A power source frequency is in the range of from 1 to 120 MHz, preferably, 13 to 60 MHz. A heat temperature for a substrate is at most  $300^\circ\text{C}$ , preferably, 20 100 to  $250^\circ\text{C}$ . As impurity elements in the film, atmospheric constituents such as oxygen, nitrogen, carbon, and the like have preferably concentrations of  $1 \times 10^{20}\text{ atoms/cm}^3$  or less, especially, oxygen concentration is  $5 \times 10^{19}/\text{cm}^3$  or less, preferably,  $1 \times 10^{19}\text{ atoms/cm}^3$  or less. By mixing a rare gas 25 element such as helium, argon, krypton, or neon into the SAS

to enhance the lattice distortion, stability of the SAS can be increased. Accordingly, favorable SAS can be obtained. A SAS layer formed by a hydrogenation gas can be stacked over a SAS layer formed by a fluoride gas as a semiconductor layer.

5           FIG. 29A illustrates a structure of a display panel in which a signal input to a scanning line or a signal line is controlled by an external driver circuit. As illustrated in FIG. 30A, a driver IC 2751 can be mounted over the substrate 2700 by COG (Chip on Glass) technique. As another mounting form,  
10   TAB (Tape Automated Bonding) technique as illustrated in FIG. 30B can be used. The driver IC may be formed using a single crystalline semiconductor substrate, or formed by forming a circuit by a TFT over a glass substrate. In FIGS. 30A and 30B, the driver IC 2751 is connected to an FPC (Flexible Printed  
15   Circuit) 2750.

          In the case that a TFT provided to a pixel is formed by SAS, a scanning line driver circuit 3702 can be integrally formed over a substrate 3700 as illustrated in FIG. 29B. In FIG. 29B, a pixel portion 3701 is controlled by an external  
20   driver circuit connected to a signal line driver circuit 3704 as is the case with FIG. 29A. In the case that the TFT provided to the pixel is formed by a polycrystalline (microcrystalline) semiconductor or a single crystalline semiconductor, each of which has high mobility, a display panel illustrated in FIG.  
25   29C can be formed by a pixel portion 4701, a scanning line driver

circuit 4702, and a signal line driver circuit 4704 being integrally formed over a substrate 4700.

An embodiment of the present invention is explained with reference to FIGS. 1A to 1H. FIGS. 1A to 1D are top views of  
5 a pattern. FIGS. 1E to 1H are cross-sectional view taken along line G-H of FIGS. 1A to 1D. FIGS. 1A to 1D correspond respectively to FIGS. 1E to 1H.

According to the present invention, among patterns such as a conductive layer for forming a wiring layer or an electrode,  
10 or a mask layer for forming a predetermined pattern; a display device is manufactured by forming at least one or more of the patterns by a method by which a pattern can be formed selectively. As the method by which a pattern can be formed selectively, droplet discharging (squirting) (also referred to as ink  
15 jetting depending on its method) by which a conductive layer or an insulating layer is formed to form a predetermined pattern by discharging (squirting) selectively a composition prepared for specific purposes is used. Alternatively, a method by which a pattern can be transferred or drawn, for example, printing  
20 (method such as screen printing or offset printing by which a pattern is formed) can be used.

According to this embodiment, a method by which a composition including a fluid pattern is selectively discharged (squirted) as droplets is used. Droplets containing a pattern  
25 formation material are discharged to a subject formation region

to be provided with a pattern, and solidified by baking, drying, and the like. Accordingly, a pattern can be formed. In the present invention, a pattern formation region is pre-treated.

FIG. 28 illustrates one mode of a droplet discharging device that is used for forming a pattern. Each of the heads 1405 and 1412 of the droplet discharging means 1403 is connected to a controlling means 1407. The heads can draw a pattern that is preliminarily programmed by controlling the controlling means by a computer 1410. The timing of the drawing, for example, may be based on the marker 1411 formed over the substrate 1400. Alternatively, the base point may be decided on the basis of the edge of the substrate 1400. The base point is detected by an imaging means 1404 such as a CCD, converted into a digital signal by an image processing means 1409, and recognized by the computer 1410 to generate a control signal. Then, the control signal is sent to a controlling means 1407. Of course, information on a pattern that should be formed over the substrate 1400 is stored in a storing medium 1408. The control signal can be sent to the controlling means 1403 based on the information to control independently each head 1405, 1412 of the droplet discharging means 1403. A material for discharging is supplied to the heads 1405 and 1412 through material supply sources 1413 and 1414.

The interior of the head 1405 has a space for being filled with a liquid material as indicated by dotted line 1406 and a

nozzle that is a discharge opening. Although not shown, the head 1412 has the same interior structure as that of the head 1405. By providing nozzles having different sizes to the heads 1405 and 1412, a conductive material and an organic or inorganic material can be respectively discharged and drawn at a time, and different materials to have different widths; or same materials can be discharged simultaneously from a plurality of nozzles and drawn in order to improve throughput in the case of drawing over a wide region such as a interlayer film. In the case of using a large substrate, the heads 1405 and 1412 scan freely over the substrate by moving in the directions of arrows to set freely a drawing region, and draw directly a plurality of same patterns over one substrate.

According to a pattern formation method for forming a conductive layer by droplet discharging, a pattern is formed according to the procedure, that is, a pattern formation material processed into particles is delivered, and the delivered material is fused or fusion bonded by baking to be solidified. Therefore, most patterns formed by sputtering or the like have a column structure, whereas the pattern is in a polycrystalline state having many grain boundaries.

As illustrated in FIG. 1A, as pretreatment, a region having wettability that is different from that of a pattern formation material is formed to the periphery region including a subject formation region for being provided with a pattern

over the substrate 50. The difference in wettability is a relative relationship between the subject formation regions. The regions may have a difference in wettability in the degree of being different from that of the pattern formation material within the subject pattern. The region having different wettability has a different contact angle from that of another region. A region having a large contact angle is a region having low wettability (hereinafter, the region may be referred to as a low wettability region), whereas a region having a small contact angle is a region having high wettability (hereinafter, the region may be referred to as a high wettability region). In the case that a contact angle is large, a liquid composition having fluidity does not spread over the surface nor wet the surface. In the case that a contact angle is small, a liquid composition having fluidity spreads over the surface and wets sufficiently the surface. In the present invention, a contact angle of the region having different wettability has preferably a difference of 30° or more, more preferably, 40° or more. According to this embodiment, a mask 51 is formed to form a low wettability substance 52 over another region in the substrate 50 using the mask 51 (FIGS. 1A and 1E). Thereafter, regions having different wettability 53 and 64 are formed by removing the mask 51 (FIGS. 1B and 1F). In this embodiment, a region having low wettability 64 is referred to as a low wettability region 64, whereas a region having high wettability 53 is

referred to as a high wettability region 53.

A droplet 55 of a composition containing a pattern formation material is discharged by droplet discharging so as to be crossing a boundary between the high wettability region 53 and the low wettability region 64. Discharging the composition may be started from either of the high wettability region 53 or the low wettability region 64. The composition containing a pattern formation material is discharged from a nozzle 54 as the droplet 55 to form a pattern 56 (FIGS. 1C and 1G).

Immediately after discharging the composition, the pattern formation material formed in the pattern 56 does not settle in the low wettability region 64 due to the difference in wettability of the subject formation region, and flows partly from the boundary between the high wettability region 53 and the low wettability region 64 to the high wettability region 53. This arises from the fact that the composition containing a pattern formation material cannot sufficiently get wet in the low wettability region 64 that has low wettability with respect to the composition containing a pattern formation material, and so the composition is difficult to be solidified and flows to the high wettability region 53 that has higher stability than that of the low wettability region 53. As a result, due to fluidity and the difference in wettability with respect to the subject formation region, the composition containing pattern



formation material that is formed into the form of the pattern 56 immediately after discharging is changed its form into a pattern 57 to be stabilized. The pattern 57 formed over the low wettability region 64 is formed to be fine since a part of 5 the composition flows to the high wettability region 53. Therefore, a pattern that is finer than the pattern formed by droplet discharging can be freely formed.

On the contrary, in the case that a composition containing pattern formation material is discharged to only a high 10 wettability region, a droplet is repelled by a low wettability region that surrounds the high wettability region, accordingly, the composition discharged to the high wettability regions serves as a bank at a boundary between the high wettability region and the low wettability region. Therefore, a pattern 15 can be increased its width and thickness since a composition containing a pattern formation material having fluidity can settle in the high wettability region.

According to the present invention, a fine pattern can be formed in order to form a fine pattern such as an electrode 20 layer by moving a discharged extra droplet into an adjacent high wettability region even if a large nozzle is used. The pattern that is flown in the high wettability region may be removed by etching. Alternatively, another pattern material may be discharged over the pattern in the high wettability region and 25 drawn to form into a part of a wiring layer or the like having

a wide width pattern. In this case, discharging a droplet to only the high wettability region surrounded by the low wettability region leads to increase a width and a thickness of a pattern formed by the composition discharged over the high wettability region. According to the present invention, a fine wiring or electrode can be formed with well controllability; and reliability can be improved, loss of material can be prevented, manufacturing yields can be improved, and costs can be reduced.

10 In this embodiment, a low wettability substance that is formed as pretreatment having an ultra thin thickness is not required to be formed in a film depending on a formation condition. The method for forming a low wettability region (region having comparative low wettability) and a high wettability region (region having comparative high wettability) is not limited to this embodiment. Any method can be used. Though a low wettability substance is formed in this embodiment; on the contrary, a substance that enhances wettability may be formed. All one have to do is forming a region having different levels of wettability by using any method.

Treatment for selectively enhancing wettability or lessening wettability may be carried out by forming a substance at the periphery of a subject formation region. As the treatment, heat treatment, light irradiation treatment, and the

like can be used. For example, ultraviolet light that can decompose a substance that lessens wettability is emitted; the substance that lessens wettability at an irradiated region is recomposed and removed; and an effect of lessening wettability is diminished, then, a high wettability region is formed. In this instance, a wavelength of light may be appropriately selected depending on the substance that lessens wettability. Light having high energy at 300 nm or less is preferably used. A substance that has an effect of improving adhesiveness may be formed over the periphery of a subject formation region as a base film. In this instance, a region having different wettability may be formed over the base film.

Alternatively, a substance is formed selectively over a region to which a high wettability region is formed later, and a substance having an effect of lessening wettability is formed over the foregoing substance. Thereafter, the substance formed over the region to be a high wettability region is activated by heat treatment or light irradiation treatment to enhance wettability, and a high wettability region can be formed. As a substance for forming the high wettability region, a substance having a light catalytic function (hereinafter, light catalytic substance) can be used. A low wettability substance is formed over the light catalytic substance to form a low wettability region, and the low wettability region is irradiated with light. The selectively formed light catalytic

substance is activated by light irradiation since it has a light catalytic function. Further, the low wettability substance is decomposed and removed, and a high wettability region can be formed at the region where the low wettability substance is  
5 formed.

Titanium oxide ( $\text{TiO}_x$ ), strontium titanate ( $\text{SrTiO}_3$ ), cadmium selenide ( $\text{CdSe}$ ), potassium tantalate ( $\text{KTaO}_3$ ), cadmium sulfide ( $\text{CdS}$ ), zirconium oxide ( $\text{ZrO}_2$ ), niobium oxide ( $\text{Nb}_2\text{O}_5$ ), zinc oxide ( $\text{ZnO}$ ), iron oxide ( $\text{Fe}_2\text{O}_3$ ), tungsten oxide ( $\text{WO}_3$ ), or  
10 the like is preferably used as the photocatalytic substance. The photocatalytic substance may be irradiated with light at an ultraviolet light region (wavelength of 400 nm or less, preferably, 380 nm or less) to be photocatalytically activated. The photocatalytic substance can be formed by dip coating of  
15 sol-gel, spin coating, droplet discharging, ion plating, ion beam, chemical vapor deposition (CVD), sputtering, RF magnetron sputtering, plasma spraying, or anodic oxidation. In addition, the substance does not need to have continuity as a film, depending on its formation method. In the case that the  
20 photocatalytic substance is made of an oxide semiconductor including a plurality of metals, the photocatalytic substance can be formed by mixing and melting a salt of a constituent element. The photocatalytic substance may be baked or dried when it is necessary to remove solvent in the case of forming  
25 the photocatalytic substance by a coating method such as dip

coating or spin coating. Specifically, it may be heated at a predetermined temperature (for example, 300 °C or more), preferably, in an atmosphere including oxygen.

According to the heat treatment, the photocatalytic substance  
5 can have a predetermined crystal structure. For example, it has an anatase type or a rutile-anatase mixed type crystal structure. The anatase type is preferentially formed in a low temperature phase. Therefore, the photocatalytic substance may also be heated even if it does not have a predetermined  
10 crystal structure. In addition, the photocatalytic substance can be formed at plural numbers of times to obtain a predetermined film thickness in the case of being formed by a coating method.

As a material for forming the mask 51, a resin material  
15 such as epoxy resin, acrylic resin, phenol resin, novolac resin, melamine resin, or urethane resin is used. Further, the mask 51 can be formed by droplet discharging using an organic material such as benzocyclobutene, parylene, flare, or polyimide having permeability; a compound material formed by  
20 polymerization of siloxane-based polymer or the like; a composition material containing water-soluble homopolymer and water-soluble copolymer; or the like. Alternatively, a commercial resist material including a photosensitizer, for example, a typical positive type resist such as a novolac resin,  
25 a naphthoquinonediazide compound that is a photosensitizer,

base resin that is negative type resist, diphenylsilanediol, or an acid generating agent may be used. In any case of using any material, surface tension and viscosity are appropriately adjusted by adjusting concentration of solvent or adding a surface-active agent or the like.

Treatment for enhancing wettability means to make the function of fixing a droplet at a discharged place (also referred to adherence or fixing strength) be weaker than that of the periphery region. Further, the treatment also means to modify a region and to enhance adhesiveness between the region and the droplet by heat treatment or light (laser light or the like) irradiation. Only the surface of a region that is in contact with a droplet to fix it thereto may have the wettability. It is not always required that a whole region in a direction of the thickness includes the same level of the wettability.

The substance that enhances or lessens wettability formed as pretreatment may be left after forming the pattern, or unnecessary portion may be removed after forming the pattern. The unnecessary portion may be removed by using the pattern as a mask, ashing with oxygen, etching, or the like.

As an example of a composition of solution for forming the low wettability region, a silane-coupling agent, which is represented by a chemical formula:  $R_n-Si-X_{(4-n)}$  ( $n=1, 2, 3$ ), is used. In the foregoing formula, R includes a group that is comparatively inactive, for example, an alkyl group or the like;

and X includes a hydrolytic group capable of coupling by means of shrinking with a hydroxyl group such as a methoxy group, an ethoxy group, or an acetoxy group over the surface of a substrate or adsorption water.

5 Wettability can be further enhanced by using fluorite silane coupling agent (fluoroalkylsilane (FAS)) having a fluoroalkyl group as R, which is a typical example of the silane-coupling agent. The fluoroalkyl group R of FAS has a structure of  $(CF_3)(CF_2)_x(CH_2)_y$ , wherein x is 0 or more and 10 or less and y  
10 is 0 or more and 4 or less. When a plurality of R or X is coupled with Si, all of the R or X may be the same or different. As a typical example of the FAS, fluoroalkylsilane such as heptafluorotetrahydrodecyltriethoxysilane, heptafluorotetrahydrodecyltrichlorosilane,  
15 tridecafluorotetrahydrooctyltrichlorosilane, and trifluoropropyltrimethoxysilane can be used.

As solvent of solution for forming the low wettability region, hydrocarbon-based solvent such as n-pentane, n-hexane, n-heptane, n-octane, n-decane, dicyclopentane, benzene,  
20 toluene, xylene, durene, indene, tetrahydronaphthalene, decahydronaphthalene, and squalene; or tetrahydrofuran can be used.

As an example of a composition of solution for forming the low wettability region, a substance having a fluorocarbon chain  
25 (fluorinated resin) can be used. As the fluorinated resin,

polytetrafluoroethylene (PTFE; 4-fluorinated ethylene resin),  
perfluoroalkoxy alkane (PFA; 4-fluorinated ethylene  
perfluoroalkylvinylether copolymer resin),  
perfluoroethylenepropene copolymer (PFEP; 4-fluorinated  
5 ethylene 6-fluorinated propylene copolymer resin),  
ethylene-tetrafluoroethylene copolymer (ETFE; 4-fluorinated  
ethylene-ethylene copolymer resin), polyvinylidene fluoride  
(PVDF; fluorinated vinylidene resin),  
polychlorotrifluoroethylene (PCTFE; 3-fluorinated ethylene  
10 chloride resin), ethylene-chlorotrifluoroethylene copolymer  
(ECTFE; 3-fluorinated ethylene chloride-ethylene copolymer  
resin), polytetrafluoroethylene-perfluorodioxole copolymer  
(TFE/PDD), polyvinyl fluoride (PVF; fluorinated vinyl resin),  
or the like can be used.

15 A low wettability region may be formed by using an organic  
material that does not form a low wettability region (that is,  
the organic material forms a high wettability region) and  
performing treatment by  $\text{CF}_4$  plasma. For example, a material  
formed by mixing water-soluble resin such as polyvinyl alcohol  
20 (PVA) into solvent such as  $\text{H}_2\text{O}$  can be used. Alternatively, the  
PVA may be used with another water-soluble resin in combination.  
An organic material (a material, which has a skeleton formed  
by the bond of silicon (Si) and oxygen (O), which includes at  
least hydrogen, and which may include one selected from the  
25 group consisting of fluoride, alkyl group, and aromatic



hydrocarbon as a substituent) can be used. Even if a material having low wettability is used, the wettability can be further lessened by plasma treatment or the like.

In order to improve adhesiveness between the pattern and the subject formation region, a base film may be formed. For example, a titanium oxide film may be formed over a substrate as a conductive film in order to improve adhesiveness in the case that a conductive material containing silver is coated over a substrate to form a silver wiring. Since the adhesiveness between the titanium oxide film and the conductive material containing silver is well, the reliability can be improved.

According to the present invention, a desired pattern can be formed with well controllability, and so loss of material can be prevented and costs can be reduced. Therefore, a display device with high performance and high reliability can be manufactured with good yields.

#### Embodiment 2

An embodiment of the present invention is explained with reference to FIGS. 2A to 2H. FIGS. 2A to 2D are top views of a pattern. FIGS. 2E to 2H are cross-sectional views taken along line I-J of FIGS. 2A to 2D. FIG. 2A to 2D correspond respectively to FIGS. 2E to 2H.

In this embodiment, another example of forming a pattern according to the present invention is explained. In Embodiment

1, an example of forming a pattern into a fine line is explained. In this embodiment, an example of forming finely spaced apart patterns with good controllability is explained.

FIG. 2A illustrates the state that a low wettability substance 52 that has an effect of imparting low wettability is removed from the state illustrated in FIGS. 1D using a pattern 57 as a mask. As illustrated in FIG. 2E, only the low wettability substance 52 is left below the pattern 57 and the periphery thereof is a high wettability region 65. The high wettability region has high wettability since it has not the low wettability substance 52. Then, only the pattern 57 is removed by an etching method having a high selective ratio to the low wettability substance 52. As the etching method, either a dry etching method or a wet etching method may be used. Alternatively, ashing or the like can be used as the etching method. In this instance, an etching gas or etchant, each of which has a high selective ratio to the low wettability substance and a pattern formation material is preferably used.

When the pattern 57 is removed, the left low wettability substance 52 exists at the top surface of a substrate as a low wettability region 58. A contact angle of a composition containing a material for a pattern to be formed on the high wettability region 65 is smaller than that of the low wettability region 58. The difference in the contact angles is preferably 40 ° or more. The low wettability region 58 has

a form of a fine line since it is formed by using the pattern 57 that is formed into a fine line as a mask (FIGS. 2B and 2F). A composition containing a pattern formation material is discharged as a droplet 61 having fluidity discharged from a nozzle so as to cross the low wettability region 58 and to straddle the peripheral high wettability region 65. Accordingly, a pattern 59 is formed. In this embodiment, the composition containing a pattern formation material has low wettability with respect to the low wettability 65 and has a small contact angle as is the case with Embodiment 1.

Immediately after discharging the composition, the pattern formation material formed into the form of the pattern 59 does not settle over the low wettability region 58 due to the difference in wettability of the subject formation region, and flows from the boundary between the high wettability region 65 and the low wettability region 58 to the high wettability region 65. This arises from the fact that the composition containing a pattern formation material cannot sufficiently get wet in the low wettability region 58 that has low wettability with respect to the composition containing a pattern formation material, and so the composition is difficult to be solidified and flows to the high wettability region 65 that has higher stability than that of the low wettability region 58. As a result, due to the difference in fluidity and wettability with respect to the subject formation region, the composition

containing a pattern formation material that is formed into the form of the pattern 59 immediately after discharging is changed its form into a pattern 62 and a pattern 63 to be stabilized. Therefore, the pattern 62 and the pattern 63 can be formed finely spaced apart with good controllability. In the case that the pattern 62 and the pattern 63 are electrode layers, deteriorations such as short-circuiting can be prevented. According to the present invention, wirings and the like designed to be closely-spaced and complicated by reducing in a size and a thickness can be formed with good controllability, and so a high definition display device having high reliability can be manufactured with high yields.

### Embodiment 3

This embodiment is explained with reference to FIGS. 38A to 38D. FIGS. 38A to 38D illustrates a top view of a pattern.

This embodiment shows an example of forming a pattern formed to be a fine line in Embodiment 1 is formed further longer to form a fine and long pattern.

A plurality of masks 71a, 71b, and 71c are provided spaced apart over a substrate 70. Thereafter, a low wettability substance 72 is formed by using the masks 71a, 71b, and 71c (FIG. 38A). Then, the masks 71a, 71b, and 71c are removed by etching. A low wettability region 78, and high wettability regions 73a, 73b, and 73c are selectively formed over the substrate 70 (FIG.

38B).

A droplet of a composition containing a pattern formation material having fluidity is discharged so as to be crossed the high wettability regions 73a, 73b, and 73c and to be straddled  
5 the low wettability region by droplet discharging. The composition containing a pattern formation material is discharged from a nozzle as a droplet to form a pattern 76 (FIG. 38C).

Immediately after discharging the composition, the  
10 pattern formation material formed in the pattern 76 does not settle in the low wettability region 78 due to the difference in wettability of the subject formation region, and flows partly from the boundary between the low wettability region 78, and the high wettability regions 73a to 73c to the respective  
15 adjacent high wettability regions 73a, 73b, and 73c. This arises from the fact that the composition containing a pattern formation material cannot sufficiently get wet in the low wettability region 78 that has low wettability with respect to the composition containing a pattern formation material, and  
20 so the composition is difficult to be solidified and flows to the high wettability regions 73a, 73b, and 73c that have higher stability than that of the low wettability region 78. As a result, due to the difference in fluidity and wettability with respect to the subject formation region, the composition  
25 containing a pattern formation material that is formed into the

form of the pattern 76 immediately after discharging is changed  
its form into a pattern 77 to be stabilized. The pattern 77  
formed over the low wettability region 78 is formed to be finer  
than the pattern 76 since a part of the pattern 77 flows to the  
5 high wettability regions 73a, 73b, and 73c. An amount of the  
composition that flows to the high wettability regions can be  
controlled by areas of the high wettability regions, a level  
of wettability of the high wettability regions, a difference  
in a contact angle, or viscosity or an amount of the discharged  
10 composition containing a pattern formation material. In the  
case of using a conductive material as the pattern material,  
a long and fine wiring can be formed with good controllability.  
By forming the high wettability region at a region that does  
not correspond to an opening portion such as a cross section  
15 of bus lines using wide width wirings, a display device can be  
manufactured without reducing an opening ratio of a pixel.

According to the present invention, it becomes possible  
to form a pattern to be fine and thin, and to determine freely  
the length of the pattern. Accordingly, design freedom of a  
20 pattern form can be improved. Wirings designed to be  
closely-spaced and complicated by reducing in a size and a  
thickness can be formed with good controllability, and so a high  
definition display device having high reliability can be  
manufactured with high yields.

## Embodiment 4

An embodiment of the present invention is explained with reference to FIGS. 3 to 18C. Specifically, a method for manufacturing a display device according to the present invention is explained. First, a method for manufacturing a display device having a channel etch type thin film transistor is explained. FIGS. 3 to 10 are top views of a pixel portion of a display device. FIGS. 11A to 18C are cross-sectional views taken along line K-L, A-C, and B-D of FIGS. 3 to 10, respectively.

As a substrate 100, a glass substrate made of barium borosilicate glass, alumino-borosilicate glass, a quartz substrate, a silicon substrate, a metal substrate, a stainless substrate, or a plastic substrate that offers resistance to process temperature of this manufacturing process is used. The surface of the substrate 100 may be polished by a CMP method so as to be planarized. An insulating layer may be formed over the substrate 100. The insulating layer is a single layer or a laminated layer by using an oxide material containing silicon or a nitride material containing silicon by a known method such as CVD, plasma CVD, sputtering, or spin coating. The insulating layer is not always required to be formed, but the insulating layer has an effect of shielding a contamination substance from the substrate 100. In the case that a base layer is formed in order to prevent contamination due to the glass substrate, a plurality regions having different levels of wettability (high

wettability region and low wettability region) are formed on the base layer.

In this embodiment, in order to make difference in wettability to form each of the high wettability region and the low wettability region, the high wettability region is covered by a mask and a low wettability substance is formed to a region that is not covered by the mask to reduce wettability of the region. Further, the difference in wettability can be confirmed by a contact angle. The difference of the contact angles is preferably 40 ° or more. However, the present invention is not limited thereto, various methods as explained in Embodiment 1 can be used. According to this embodiment, a mask 101 and a mask 125 are formed in a region that is provided with a gate wiring layer afterward.

The masks 101 and 125 can be formed by dip coating of sol-gel, spin coating, droplet discharging, ion plating, ion beam, chemical vapor deposition (CVD), sputtering, RF magnetron sputtering, or plasma spraying. The masks 101 and 125 may be baked or dried when it is necessary to remove solvent in the case of forming the mask by a coating method such as dip coating or spin coating methods. In the case of using a method of forming a pattern directly to a subject formation region such as droplet discharging, a patterning process is not always required, and so a manufacturing process can be simplified.

As a material for forming the masks 101 and 125, a resin



material such as epoxy resin, acrylic resin, phenol resin, novolac resin, melamine resin, or urethane resin is used. In addition, the mask can be formed by droplet discharging using an organic material such as benzocyclobutene, parylene, flare, or polyimide having permeability; a compound material formed by polymerization of siloxane-based polymer or the like; a composition material containing water-soluble homopolymer and water-soluble copolymer; or the like. Alternatively, a commercial resist material including a photosensitizer, for example, a typical positive type resist such as a novolac resin, a naphthoquinonediazide compound that is a photosensitizer, base resin that is negative type resist, diphenylsilanediol, an acid generating agent, or the like may be used. In any case of using the material, surface tension and viscosity are appropriately adjusted by adjusting concentration of solvent or adding a surface-active agent or the like.

In this embodiment, the masks 101 and 125 are made from polyimide by droplet discharging. The masks 101 and 125 are required to be masks to prevent a low wettability substance from being formed. The masks 101 and 125 are removed eventually, and so a thickness or a shape may be appropriately designed. A low wettability substance is formed by using the masks 101 and 125 to form low wettability regions 102a and 102b (FIGS. 3 and 11A to 11C).

As an example of a composition of solution for forming

the low wettability region, a silane-coupling agent, which is represented by a chemical formula:  $R_n-Si-X_{(4-n)}$  ( $n=1, 2, 3$ ), is used. In the foregoing formula, R includes a group that is comparatively inactive, for example, an alkyl group; and X  
5 includes a hydrolytic group capable of coupling by means of shrinking with a hydroxyl group such as a methoxy group, a ethoxy group, or an acetoxy group over the surface of a substrate or adsorption water.

Wettability can be further enhanced by using fluorite silane  
10 coupling agent (fluoroalkylsilane (FAS)) having a fluoroalkyl group as R, which is a typical example of the silane-coupling agent. The fluoroalkyl group R of FAS has a structure of  $(CF_3)(CF_2)_x(CH_2)_y$ , wherein x is 0 or more and 10 or less and y is 0 or more and 4 or less. When a plurality of R or X is coupled  
15 with Si, all of the R or X may be the same or different. As a typical example of the FAS, fluoroalkylsilane (hereinafter, FAS) such as heptafluorotetrahydrodecyltriethoxysilane, heptafluorotetrahydrodecyltrichlorosilane, tridecafluorotetrahydrooctyltrichlorosilane, and  
20 trifluoropropyltrimethoxysilane can be used.

As solvent of solution for forming the low wettability region, hydrocarbon-based solvent such as n-pentane, n-hexane, n-heptane, n-octane, n-decane, dicyclopentane, benzene, toluene, xylene, durene, indene, tetrahydronaphthalene,  
25 decahydronaphthalene, and squalene; or tetrahydrofuran can be

used.

As an example of a composition of solution for forming the low wettability region, a substance having a fluorocarbon chain (fluorinated resin) can be used. As the fluorinated resin,

5 polytetrafluoroethylene (PTFE; 4-fluorinated ethylene resin), perfluoroalkoxy alkane (PFA; 4-fluorinated ethylene perfluoroalkylvinylether copolymer resin), perfluoroethylenepropene copolymer (PFEP; 4-fluorinated ethylene 6-fluorinated propylene copolymer resin),

10 ethylene-tetrafluoroethylene copolymer (ETFE; 4-fluorinated ethylene-ethylene copolymer resin), polyvinylidene fluoride (PVDF; fluorinated vinylidene resin), polychlorotrifluoroethylene (PCTFE; 3-fluorinated ethylene chloride resin), ethylene-chlorotrifluoroethylene copolymer

15 (ECTFE; 3-fluorinated ethylene chloride-ethylene copolymer resin), polytetrafluoroethylene-perfluorodioxole copolymer (TFE/PDD), polyvinyl fluoride (PVF; fluorinated vinyl resin), or the like can be used.

A low wettability region may be formed by using an organic

20 material that does not form a low wettability region (that is, the organic material forming a high wettability region) and performing treatment by  $\text{CF}_4$  plasma and so on. For example, a material formed by mixing water-soluble resin such as polyvinyl alcohol (PVA) into solvent such as  $\text{H}_2\text{O}$  can be used.

25 Alternatively, the PVA may be used with another water-soluble

resin in combination. An organic material (polyimide, acryl,  
or a material, which has a skeleton formed by the bond of silicon  
(Si) and oxygen (O), which includes at least hydrogen, and which  
may include one selected from the group consisting of fluoride,  
5 alkyl group, and aromatic hydrocarbon as a substituent can be  
used. Even if a material having low wettability is used, the  
wettability can be further lessened by plasma treatment or the  
like.

In this embodiment, FAS is used as a low wettability  
10 substance. In this embodiment, the FAS is coated whole over  
a surface. However, the FAS can be coated selectively by  
droplet discharging. In this instance, the masks 101 and 125  
are not always required. Thereafter, the masks 101 and 125 are  
removed. Since regions provided with the masks 101 and 125 are  
15 not provided with a low wettability substance, the regions  
become high wettability regions 130 and 126 having comparative  
high wettability (FIGS. 4 and 12A to 12C).

A composition containing a conductive material is  
discharged from a nozzle 180a to form a gate electrode layer  
20 103 so as to be crossed over the low wettability region 102b  
and the high wettability region 130. Similarly, a composition  
containing a conductive material is discharged from a nozzle  
180b to form a gate electrode layer 103 so as to be crossed over  
the low wettability region 102b and the high wettability region  
25 126 (FIGS. 5 and 13A to 13C). Immediately after

discharging the composition, the pattern formation materials forming the gate electrode layer 103 and the gate electrode layer 127 do not settle in the low wettability region 102b due to the difference in wettability of the subject formation region, and flow partly from the boundary between the low wettability region 102b and the high wettability region 130, and the boundary between the low wettability region 102b and the high wettability region 126 to the high wettability regions 130 and 126, respectively. This arises from the fact that the composition containing a pattern formation material cannot sufficiently get wet in the low wettability region 102b that has low wettability with respect to the composition containing a pattern formation material, and so the composition is difficult to be solidified and flows to the high wettability regions 130 and 126 that have higher stability than that of the low wettability region 102b. As a result, due to the difference in fluidity and wettability with respect to the subject formation region, the composition containing a pattern formation material that is formed in the gate electrode layer 103 and the gate electrode layer 127 immediately after discharging is changed its form into a gate electrode layer 105 and a gate electrode layer 104 to be stabilized. The gate electrode layer 105 and the gate electrode layer 104 formed over the low wettability region 102b is formed to be finer than the gate electrode layer 103 and the gate electrode layer 127 since

a part of the gate electrode layer 105 and the gate electrode layer 104 flows to the high wettability regions 130 and 126. Therefore, the gate electrode layers 105 and 104 that are formed into fine lines having desired fineness can be freely formed by droplet discharging (FIGS. 6 and 14A to 14C).

The shape into which a composition flowed from a low wettability region to a high wettability region formed to be stabilized is differed depending on a contact angle, surface tension, a discharge rate, viscosity, an evaporation rate of solvent, and the like. A film thickness distribution is also determined by the foregoing various factors. Therefore, the shape is not limited to that explained in this embodiment. The gate electrode layer formed into a fine line is preferably formed to have a length in a channel direction of 10  $\mu\text{m}$  or less, more preferably, 5  $\mu\text{m}$  or less.

According to the present invention, a fine wiring or electrode can be formed with well controllability; and so reliability can be improved, loss of material can be prevented, manufacturing yields can be improved, and costs can be reduced.

As a base pretreatment, an organic based substance that serves as adhesive agent can be formed to improve adhesiveness of a pattern formed by droplet discharging. As the adhesive agent, an organic material (organic resin material); or a material, which has a skeleton formed by the bond of silicon (Si) and oxygen (O), which includes at least hydrogen, and which

may include one selected from the group consisting of fluoride, alkyl group, and aromatic hydrocarbon as a substituent can be used.

A gate wiring layer 106 is formed over a high wettability region 130 (FIG. 7). The gate wiring layer 106 is formed to connect electrically to a part of the gate electrode layer 105 that is formed previously. In this embodiment, the gate electrode layer 106 is formed by discharging a composition having conducting properties by droplet discharging. Since the gate wiring layer 106 is formed over the high wettability region 130 to be in contact with the gate electrode layer 105, a low wettability region that surrounds the high wettability region 130 serves as a bank and the gate wiring layer 106 can be exclusively formed over the high wettability region. Accordingly, the gate wiring layer 106 can be formed only over the high wettability region with good controllability. This arises from the fact that the low wettability region repels the composition even if the composition has fluidity. Therefore, a width and a thickness of a wiring can be increased since a composition containing a pattern formation material having fluidity is stayed in a high wettability region.

The gate electrode layers 104 and 105, and the gate wiring layer 106 are formed by using a droplet discharging means. As used herein, the term "droplet discharging means" is a generic term referring to a means for discharging a droplet such as a

nozzle having a discharge opening for a composition, or a head provided with one or a plurality of nozzles. A diameter of the nozzle provided with the droplet discharging means is set to be from 0.02 to 100  $\mu\text{m}$  (preferably, 30  $\mu\text{m}$  or less), and a  
5 discharge amount for one dot of the composition discharged from the nozzle is set to be from 0.001 pl to 100 pl (preferably, 0.1 pl or more to 40 pl or less, more preferably, 10 pl or less). The discharge amount for one dot increases in proportion to the diameter of the nozzle. In addition, the distance between a  
10 subject and the discharge opening is preferably as close as possible in order to discharge a droplet at a desired place. The distance is preferably set from 0.1 to 3 mm (more preferably, 1 mm or less).

As the composition discharged from the discharge opening,  
15 a solvent dissolved or dispersed with a conductive material is used. The conductive material corresponds to fine particles or dispersion nanoparticles of metal such as Ag, Au, Cu, Ni, Pt, Pd, Ir, Rh, W, and Al; a metal sulfide of Cd and Zn; an oxide such as Fe, Ti, Si, Ge, Si, Zr, Ba; and a silver halide. Moreover,  
20 the conductive material corresponds to indium tin oxide (ITO) used as a transparent conductive film, ITO formed by an indium tin oxide and a silicon oxide, organic indium, organic tin, zinc oxide, titanium nitride, or the like. However, as the composition discharged from the discharge opening, solvent  
25 dissolved or dispersed with any one of Au, Ag, and Cu is



preferably used in consideration of a specific resistance value, and more preferably, Ag and Cu having low resistance is used. However, in the case of using Ag or Cu, a barrier film is preferably provided to prevent impurities. As the barrier film,  
5 a silicon nitride film or nickel boron (NiB) can be used.

Further, a particle having a laminated structure in which a conductive material is coated by another conductive material can be used. For example, a particle having a three-laminated structure in which copper coated by nickel boron (NiB) and the  
10 nickel boron is coated by silver can be used. As the solvent, esters such as butyl acetate or ethyl acetate; alcohols such as isopropyl alcohol or ethyl alcohol; organic solvent such as methyl ethyl ketone or acetone; or the like is used. Viscosity of the composition is preferably set to 20 Pa·s or less to prevent  
15 the composition from drying and discharge the composition smoothly from the discharge opening. Further, surface tension of the composition is preferably set to 40 mN/m or less. The viscosity and the like of the composition may be appropriately adjusted depending on solvent or application. As an examples,  
20 viscosity of a composition formed by dissolving or dispersing ITO, organic indium, and organic tin into solvent is preferably set to 5 to 20 mPa·s, viscosity of a composition formed by dissolving or dispersing silver into solvent is preferably set to 5 to 20 mPa·s, and viscosity of a composition formed by  
25 dissolving or dispersing gold into solvent is preferably set

to 5 to 20 mPa·s.

Further, a conductive layer may be formed by stacking a plurality of conductive materials. In addition, plating can be performed by using copper after forming the conductive layer by droplet discharging using silver as the conductive material. As the plating, electroplating or electroless plating can be performed. The plating may be performed by soaking a substrate in a container filled with solution containing a material for plating. Alternatively, the substrate is kept to be tilted (or upright), and solution containing a material for plating is coated fluently to a surface of the substrate. In the case of performing plating by coating solution fluently to the substrate kept up, there is an advantage that a processing device is reduced its size.

The diameter of the conductor particles is preferably small as possible, preferably, a grain diameter of 0.1  $\mu\text{m}$  or less, depending on a diameter of each nozzle or a desirable pattern shape, in order to prevent each clogging of a nozzle or to make fine patterns. Each composition may be formed by a known method such as an electrolytic method, an atomization method or a wet reduction method to have generally a grain diameter of approximately 0.01 to 10  $\mu\text{m}$ . Note that, in the case of forming the composition by a gas evaporation method, the nanoparticles protected by dispersant have fine grain diameters of approximately 7 nm. In addition, in the case that the

nanoparticles are each protected by a cladding material, the nanoparticles are dispersed stably at room temperature without aggregation in solution and behave similarly to liquid. Therefore, the cladding material is preferably used.

5           According to the present invention, a composition is required to have fluidity even when it is discharged to a subject since a composite having fluidity is processed into a desired pattern while the composite can keep fluidity. A process of discharging a composition may be performed under a reduced  
10   pressure if the fluidity is continued in the composition. By discharging the composition under a reduced pressure, there is an advantage that an oxide film or the like is not formed over a conductor. After discharging a composition, either or both of a drying process and/or a baking process is performed. The  
15   drying and baking processes are both heating processes. For example, the drying process is performed at 100 °C for 3 minutes, whereas the baking process is performed at 200 to 350 °C for 15 to 30 minutes. These two processes are performed for different purposes at different temperatures for different  
20   times. The drying and baking processes are performed at a normal pressure or under a reduced pressure by laser irradiation, rapid thermal annealing, heating furnace, or the like. The timing for performing the heating processes is not especially limited. To perform well the drying and baking processes, a  
25   substrate may be heated generally at temperature of 100 to 800

°C (preferably, 200 to 350 °C), which depends on a material of the substrate. Solvent in a composition is vaporized, dispersing agent is removed chemically, and peripheral resin is hardened and contracted by this process, which leads to nanoparticles become contact with each other. Accordingly, fusion and welding are accelerated. Therefore, an obtained conductive layer may include resin that protects nanoparticles as a cladding material.

As laser irradiation, a gas laser or a solid laser, each of which is a continuous oscillation or pulse oscillation may be used. As the gas laser, an excimer laser, a YAG laser, and the like can be used. As the solid laser, a YAG laser doped with Cr, Nd, or the like; a laser using a crystal such as YVO<sub>4</sub> or GdVO<sub>4</sub>; and the like can be used. From the standpoint of absorptance of laser light, a continuous oscillated laser is preferably used. Alternatively, so-called hybrid laser irradiation method composed of a pulse oscillation laser and a continuous oscillation laser may be used. Depending on resistance of a substrate 100, a heat treatment of laser light irradiation is preferably performed for several micro seconds to several ten seconds to prevent the substrate 100 from being broken. A rapid thermal annealing (RTA) method is a treatment that applies heat for several minutes to several micro minutes by producing rapidly an increase in temperature under an inert gas using an infrared lamp or halogen lamp, each of which emits

ultraviolet light or infrared light. Since this treatment is performed instantly, only a top thin layer can be substantially heated, and a layer at the bottom is not affected by the treatment. That is, even a substrate having low heat resistance such as  
5 a plastic film is not affected by the treatment.

After discharging a composition by droplet discharging to form the gate electrode layer 105, the gate electrode layer 104, and the gate wiring layer 106, the surfaces of these layers may be pressed to be planarized by pressure to increase flatness  
10 of these layers. As a method for the pressing, a roller for scanning the surface to reduce irregularities on the surface, or a flat plate pressing against the surface may be used. When pressing the surface, a heating process may be performed. Alternatively, the surface may be softened or melted by solvent  
15 and irregularities may be removed by an air knife. Further alternatively, the surface may be polished by a chemical mechanical polishing method. The process can be applied in the case that irregularities are produced on a surface by droplet discharging and the surface is required to be planarized.

20 A gate insulating layer 116 is formed over the gate electrode layer 105, the gate electrode layer 104, and the gate wiring layer 106 (FIGS. 15A to 15C). As a material for the gate insulating layer 116, a known material such as oxides of silicon or nitrides of silicon can be used. The gate insulating layer  
25 106 can be formed by a single layer or a laminated layer. In

this embodiment, a three-laminated layer of a silicon nitride film, a silicon oxide film, and a silicon nitride film is used. Alternatively, a single layer of the forgoing layers, a single layer of a silicon oxynitride film, or a two-laminated layer  
5 can be used. Preferably, a silicon nitride film that is a fine membrane material is used. In the case of using silver or copper as a conductive layer formed by droplet discharging, forming a silicon nitride film or a NiB film can prevent dispersion of impurities and flat the surface. To form a dense insulating  
10 film at low deposition temperature, which yields hardly gate leakage current, a reaction gas including an inert gas element such as argon is used to mix the inert gas element into the insulating film.

A semiconductor film is formed. A semiconductor layer  
15 having one conductivity type is formed according to need. In this embodiment, a semiconductor layer 107, a semiconductor layer 108, an n-type semiconductor layer 109 having one conductivity type, and an n-type semiconductor layer 110 having one conductivity type are formed (FIGS. 8 and 15A to 15C).  
20 Further, an NMOS structure of an n-channel TFT using an n-type semiconductor film, a PMOS structure of a p-channel TFT using a p-channel semiconductor film, and a CMOS structure using an n-channel TFT and a p-channel TFT can be manufactured. To impart conductivity, an n-channel TFT and a p-channel TFT can  
25 be formed by doping an element imparting conductivity to form

an impurity region to the semiconductor layer.

The semiconductor layer may be formed by a known method (sputtering, LPCVD, plasma CVD, or the like). It is not limited to a material for the semiconductor layer. Preferably, the  
5 semiconductor layer is formed by silicon germanium or silicon germanium alloys.

Amorphous semiconductor (typically, hydrogenated amorphous silicon), crystalline semiconductor (typically, polysilicon), or semiamorphous semiconductor are used as a  
10 material of the semiconductor layer. The polysilicon (polycrystalline silicon) comprised so-called high temperature polysilicon using polysilicon formed through a process temperature of 800 °C or more, so-called low temperature polysilicon using polysilicon formed through a process  
15 temperature of 600 °C or less, polysilicon doped with an elements for promoting crystallization and crystallized, and the like.

As another substance, semiamorphous semiconductor or the semiconductor layer including a crystal phase in a semiconductor layer can be used.

20 In the case that a crystalline semiconductor layer is used as the semiconductor layer, a known method (laser crystallization, thermal crystallization, thermal crystallization using an element promoting crystallization such as nickel, or the like) may be used as a method for  
25 manufacturing a crystalline semiconductor layer.

Microcrystal semiconductor (semiamorphous semiconductor; SAS) can be crystallized by laser irradiation to increase crystallinity. In the case that an element promoting crystallization is not introduced, contained hydrogen in an amorphous silicon film is released so that concentration of the hydrogen is reduced to  $1 \times 10^{20}$  atoms/cm<sup>3</sup> or less by heating for one hour under nitrogen atmosphere at 500 °C. The reason of reducing the hydrogen concentration is that the amorphous semiconductor film containing much hydrogen is broken in the case of being irradiated with laser light.

A method of introducing a metal element into the amorphous semiconductor layer is not especially limited as long as the metal element can exist over the surface or the inside of the amorphous semiconductor layer by the method. For example, a sputtering method, a CVD method, a plasma treatment (including plasma CVD), an absorption method, or a coating method using solution of metal salt can be used. Among the foregoing methods, the coating method using solution is a convenient means and useful in adjusting density of the metal element. To improve wettability of the surface of the amorphous semiconductor layer and coat solution whole over the surface of the amorphous semiconductor layer, an oxide film is preferably formed by UV light irradiation in oxygen atmosphere, thermal oxidation, treatment by ozone water containing hydroxy radical or hydrogen peroxide, or the like.



Crystallization of the amorphous semiconductor layer can be performed by combining thermal treatment and laser light irradiation, or a plurality numbers of times of thermal treatment or laser light irradiation.

5       Alternatively, a crystalline semiconductor layer may be directly formed on a substrate by linear plasma method. Further alternatively, the crystalline semiconductor layer may be selectively formed over a substrate by linear plasma method.

As the semiconductor, organic semiconductor using an  
10   organic material may be used. As the organic semiconductor, a low molecular material, a high molecular material, or the like is used. Further, an organic pigment, a conductive high molecular material, or the like can also be used.

In this embodiment, amorphous semiconductor is used as  
15   the semiconductor. A semiconductor layer is formed, and an n-type semiconductor layer as a semiconductor layer having one conductivity type is formed by plasma CVD or the like.

The semiconductor layer and the n-type semiconductor layer are patterned simultaneously by using a mask made from  
20   insulator such as resist, polyimide, or the like to form the semiconductor layer 107, the semiconductor layer 108, the n-type semiconductor layer 109, and the n-type semiconductor layer 110 (FIGS. 8 and 15A to 15C). As a material for forming the mask, a resin material such as epoxy resin, acrylic resin,  
25   phenol resin, novolac resin, melamine resin, or urethane resin

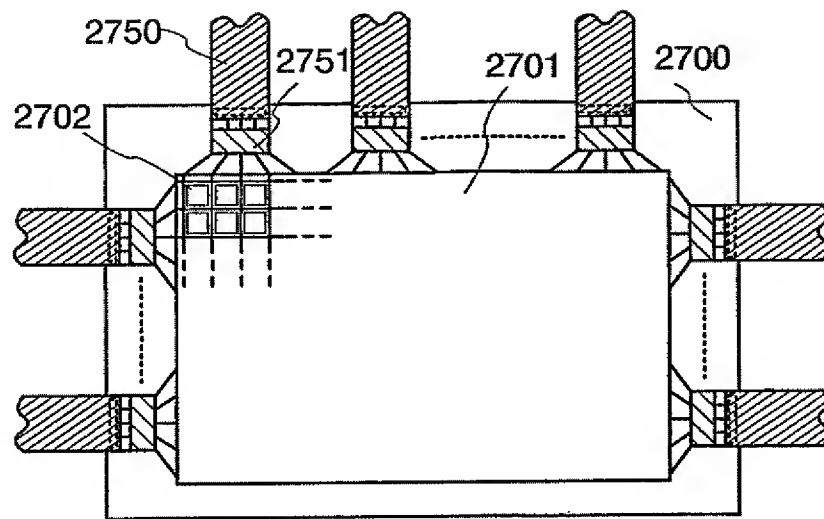


FIG. 30A

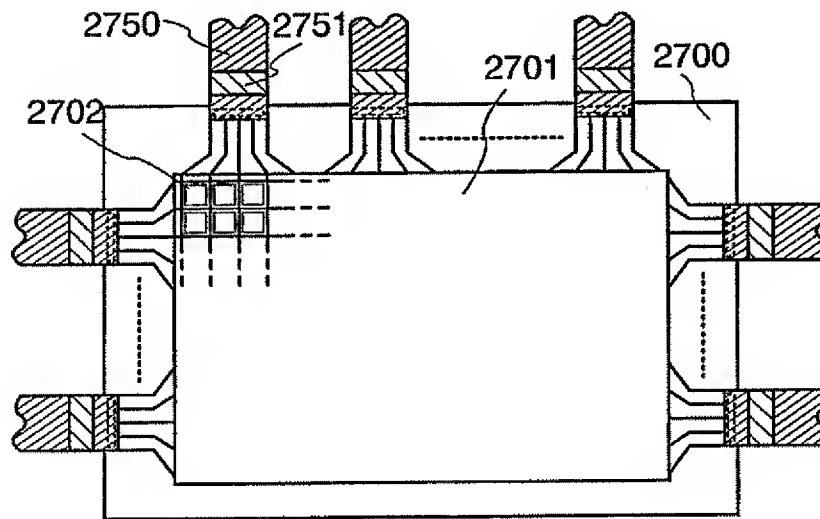


FIG. 30B

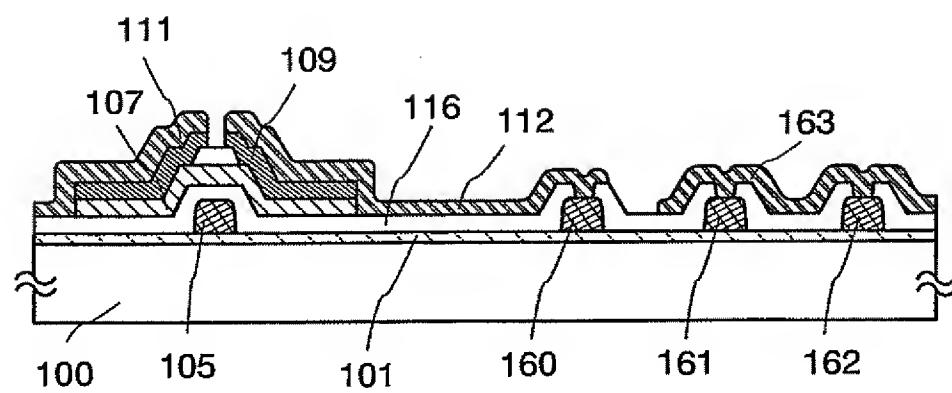


FIG. 31

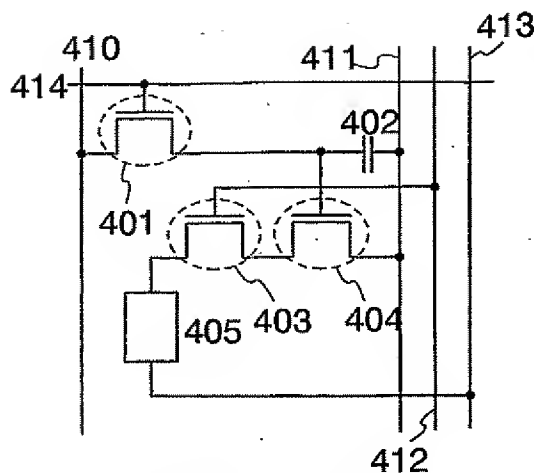


FIG. 32A

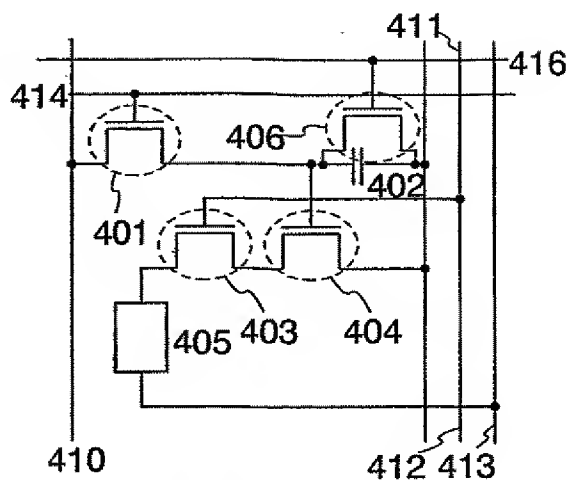


FIG. 32B

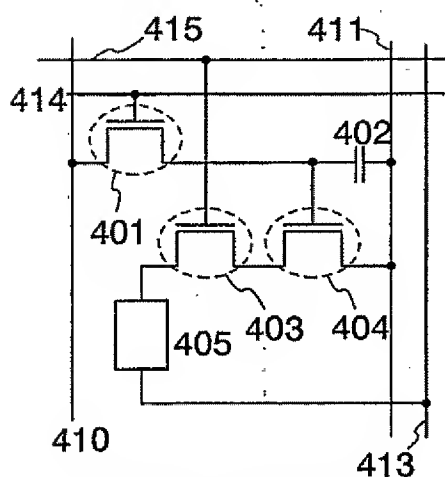


FIG. 32C

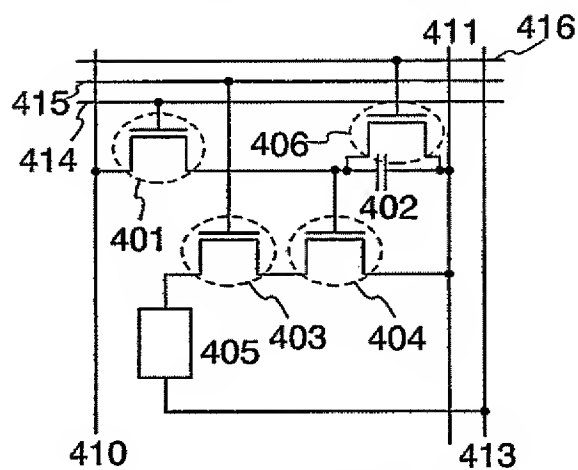


FIG. 32D

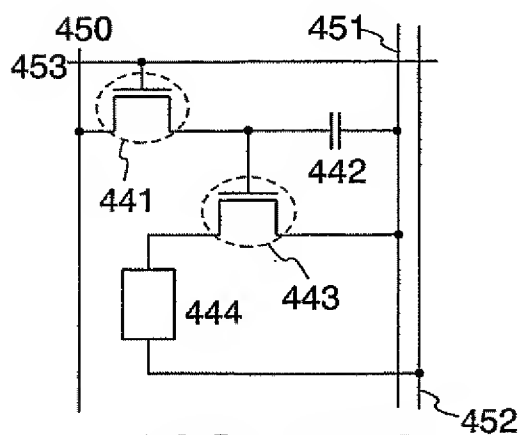


FIG. 32E

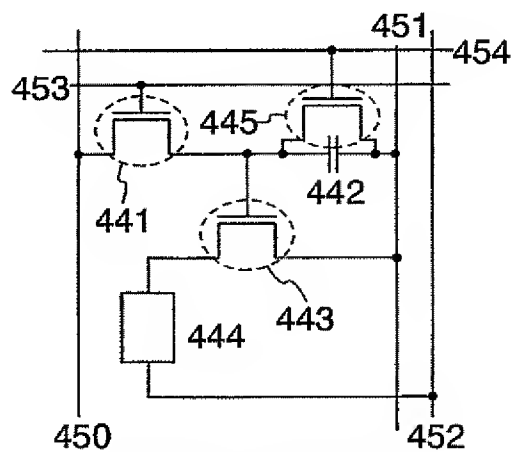


FIG. 32F

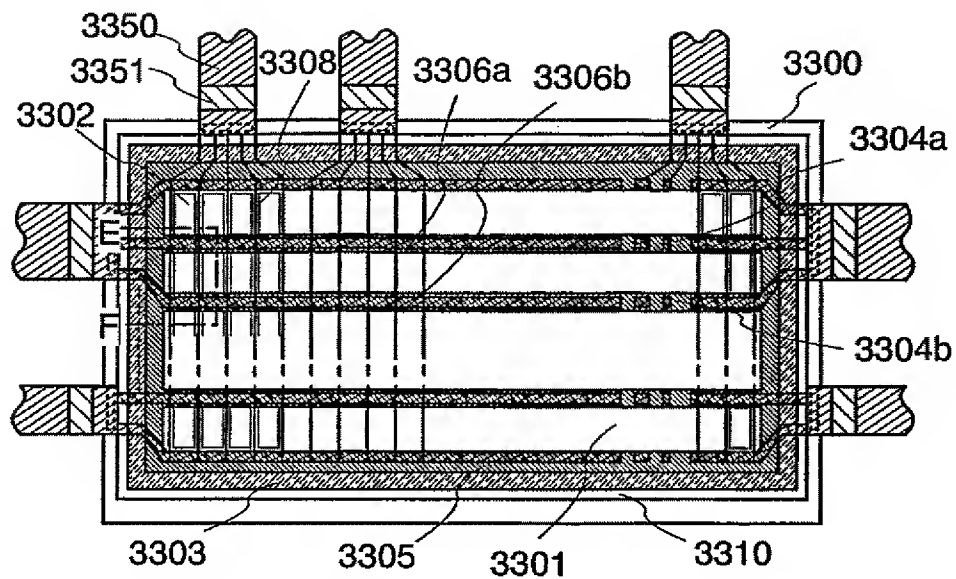
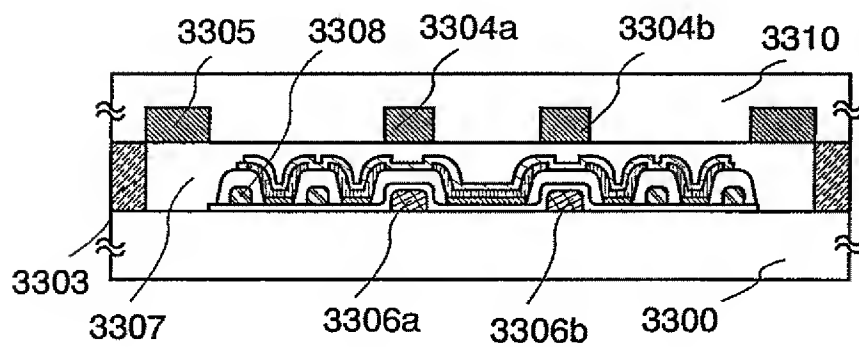


FIG. 33A



**FIG. 33B**

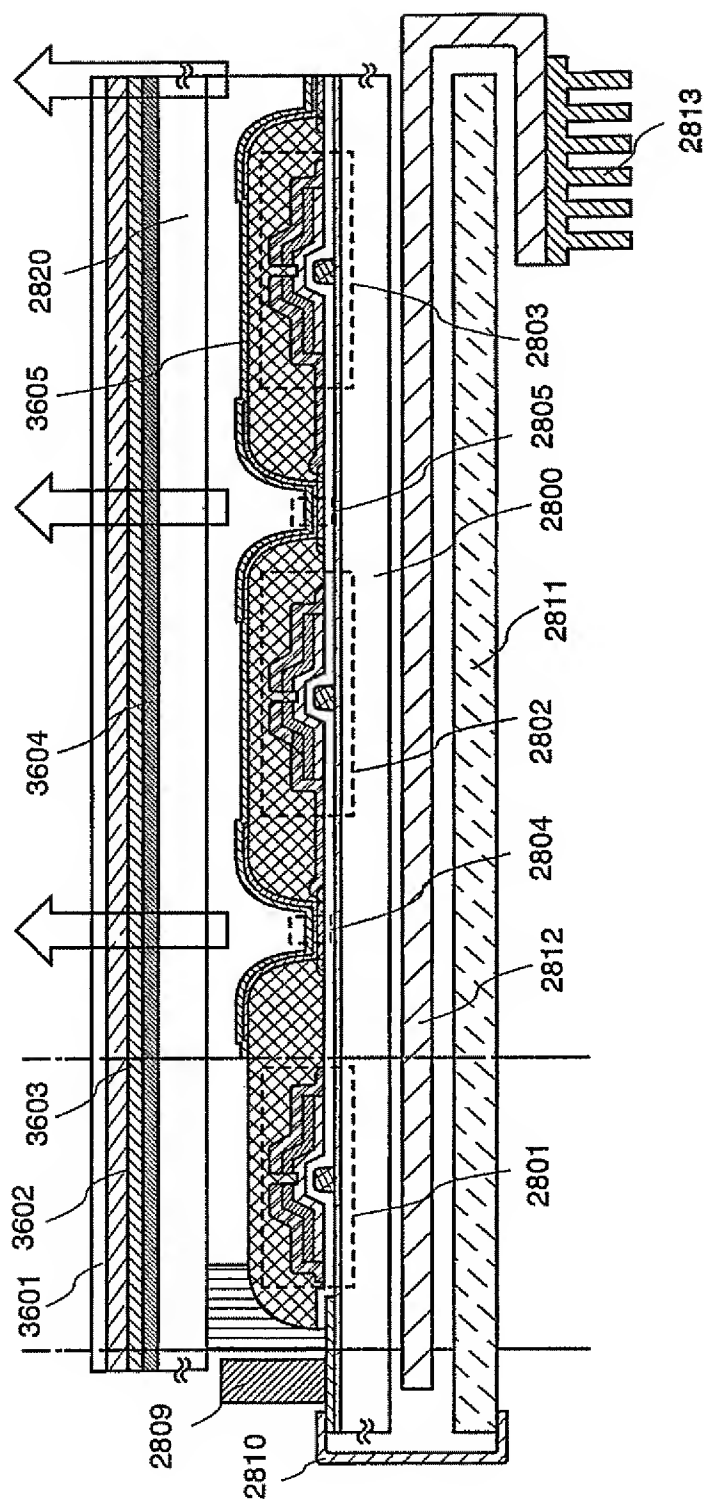


FIG. 34

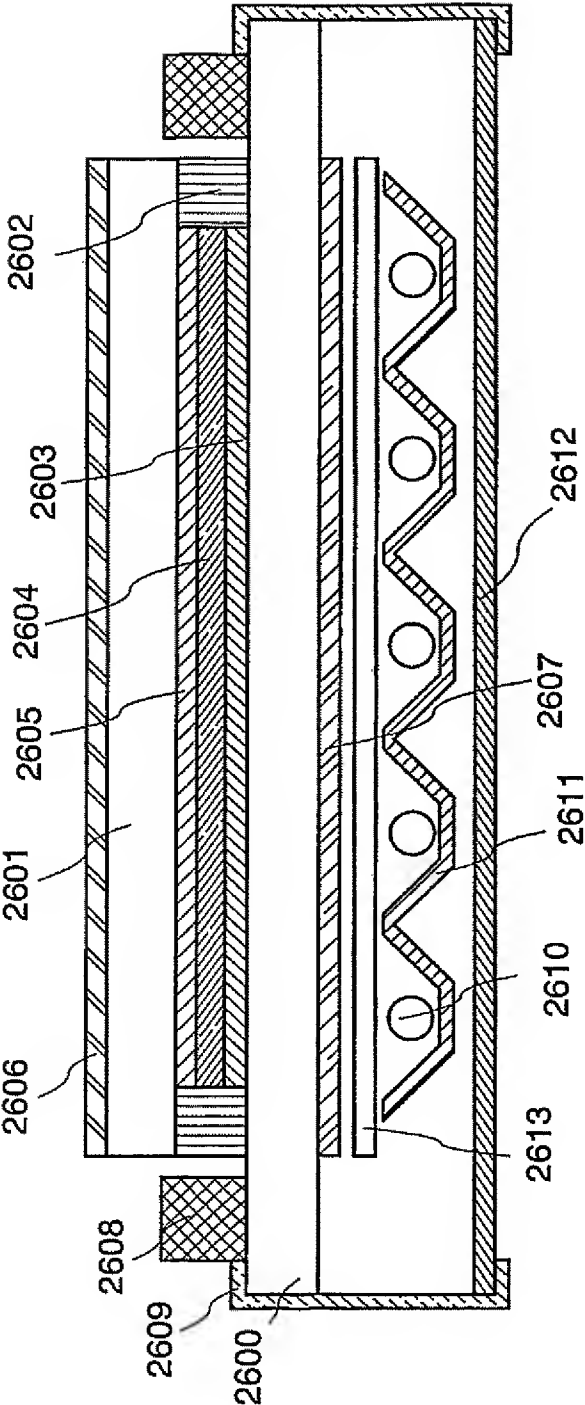


FIG. 35

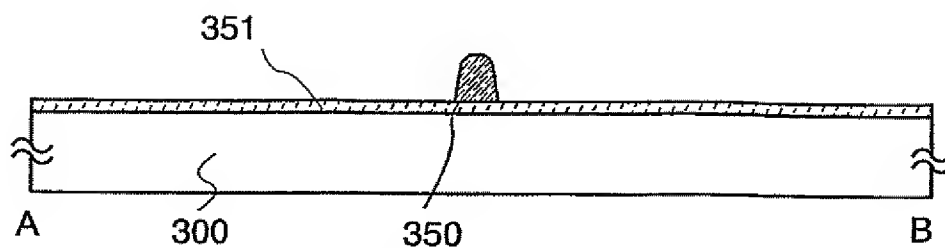


FIG. 36A

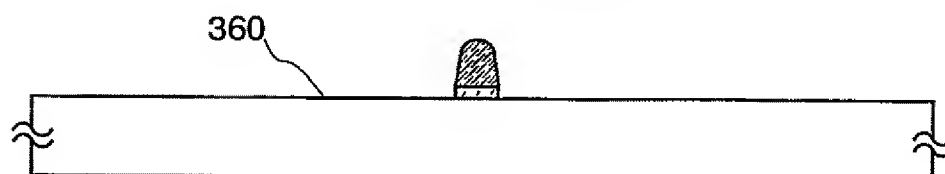


FIG. 36B

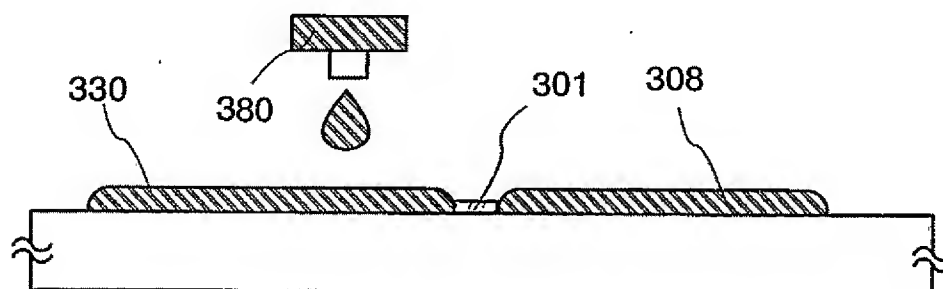


FIG. 36C

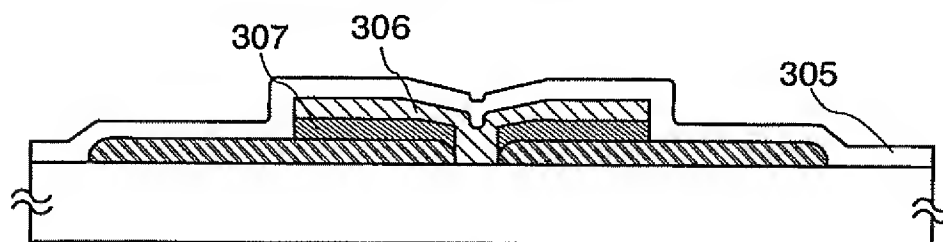


FIG. 36D

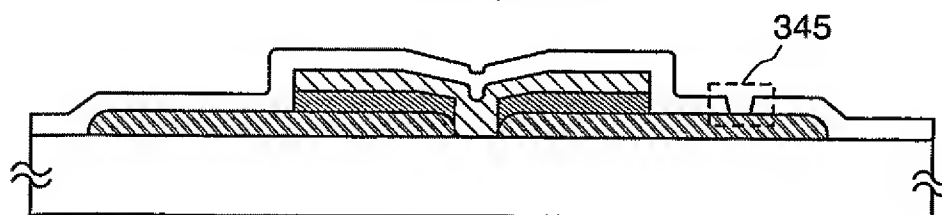


FIG. 36E



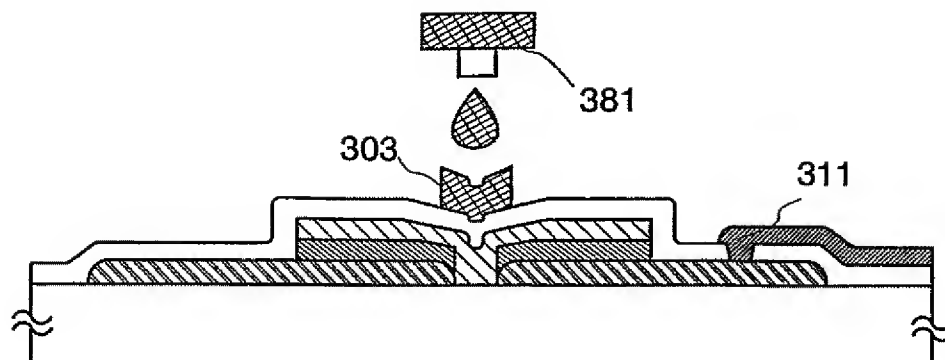


FIG. 37A

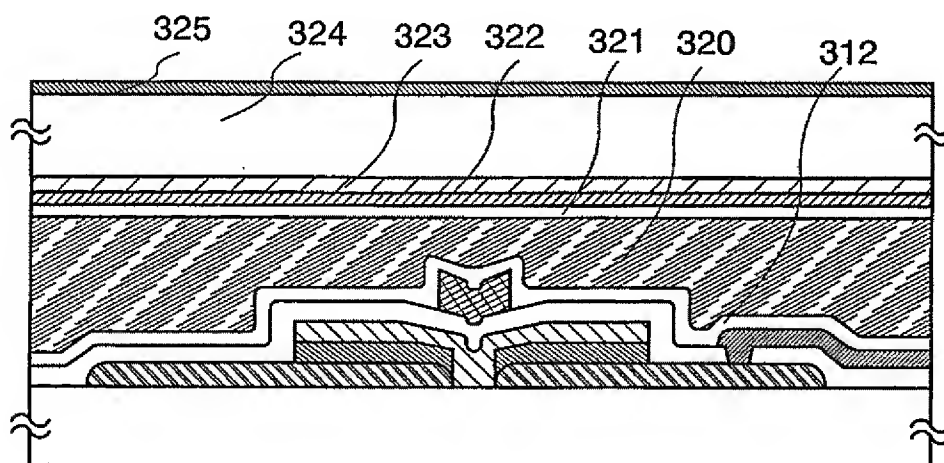


FIG. 37B

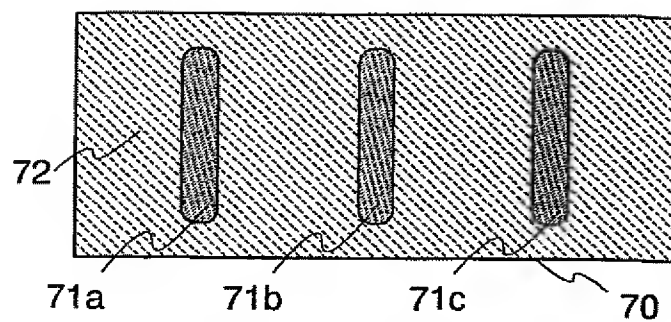


FIG. 38A

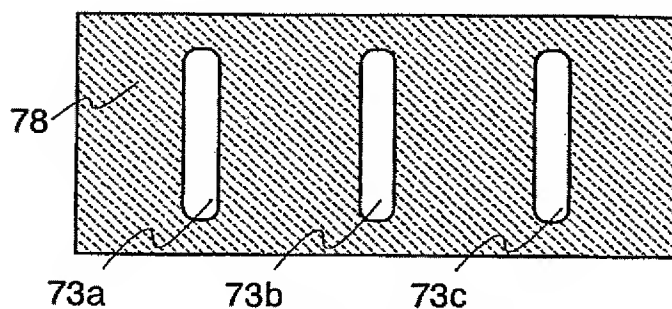


FIG. 38B

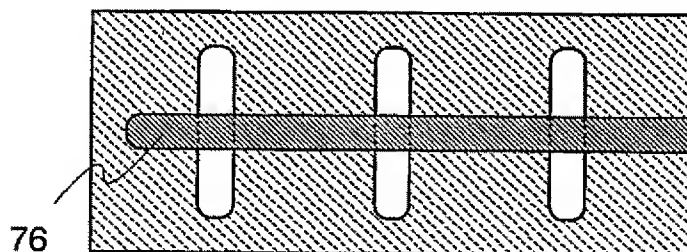


FIG. 38C

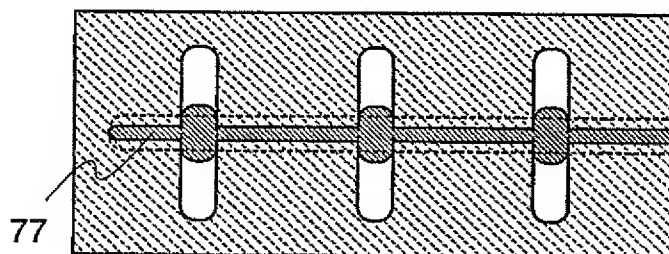


FIG. 38D

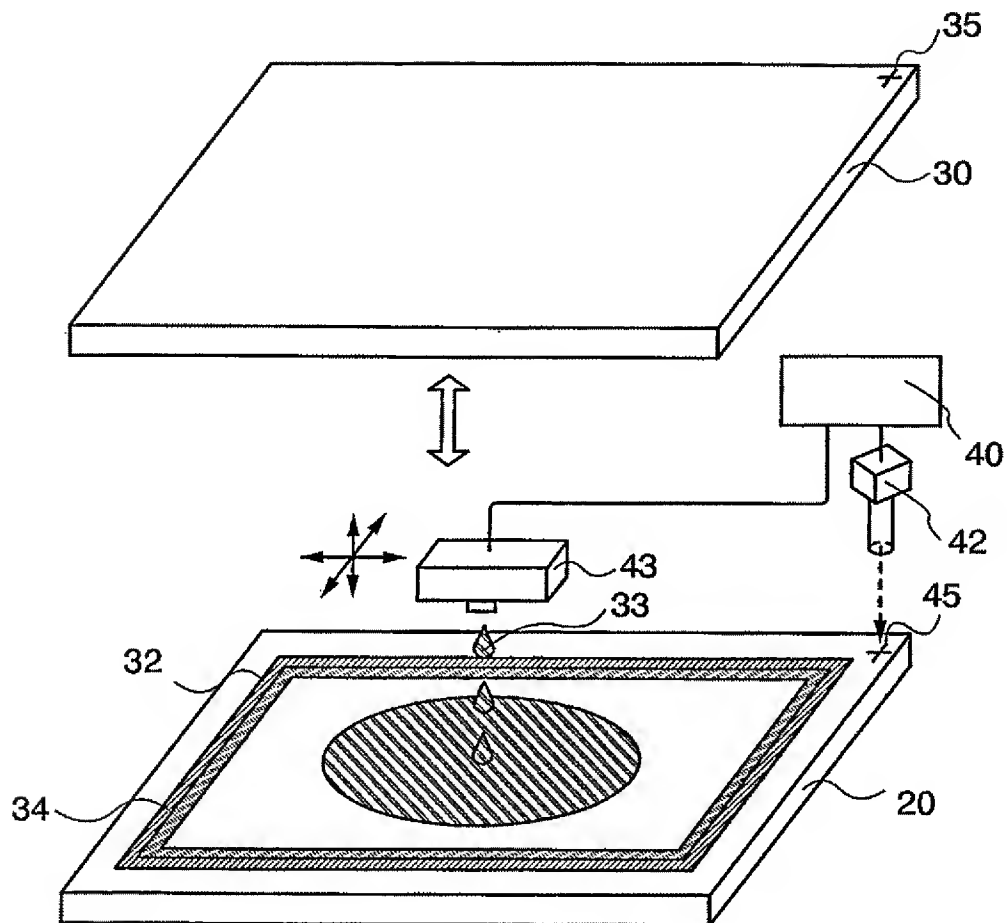


FIG. 39

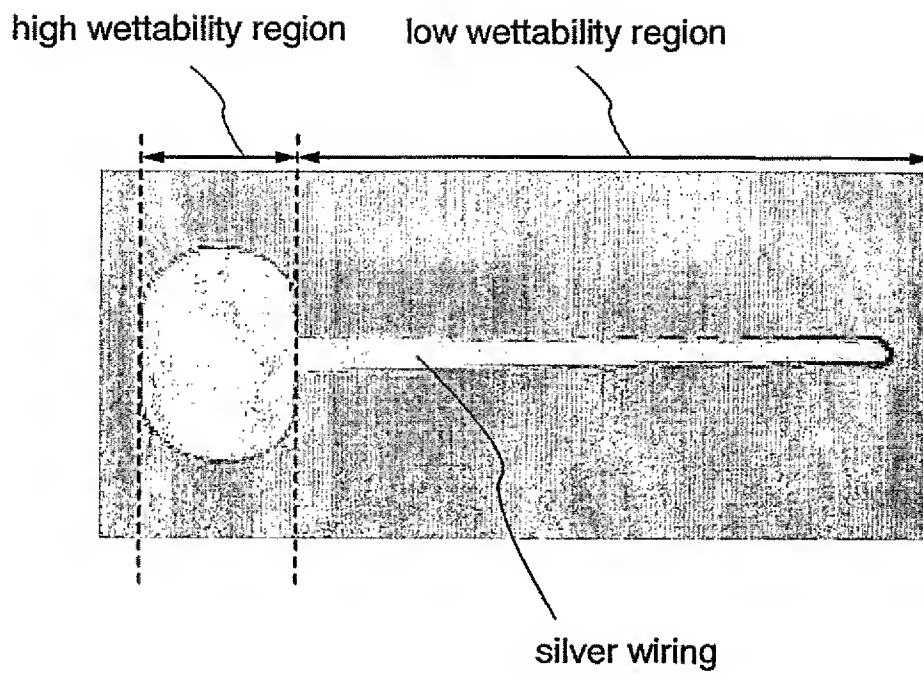


FIG. 40

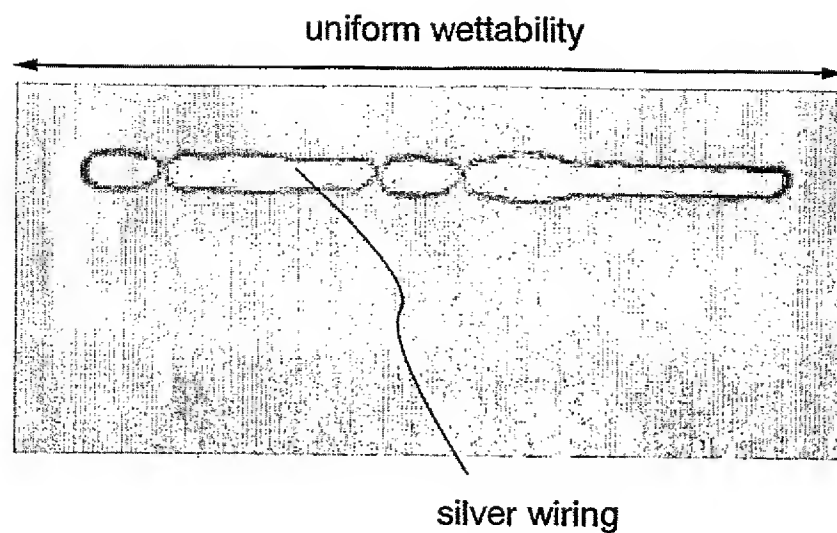


FIG. 41A

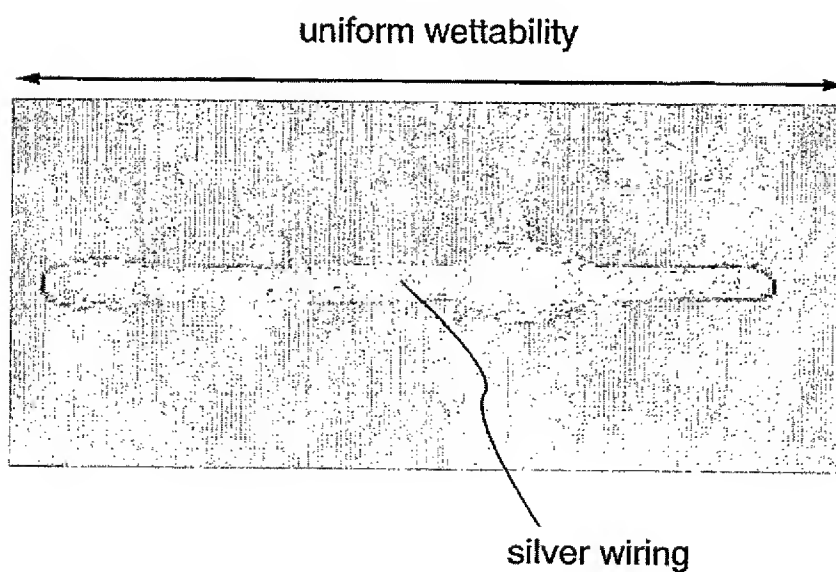


FIG. 41B

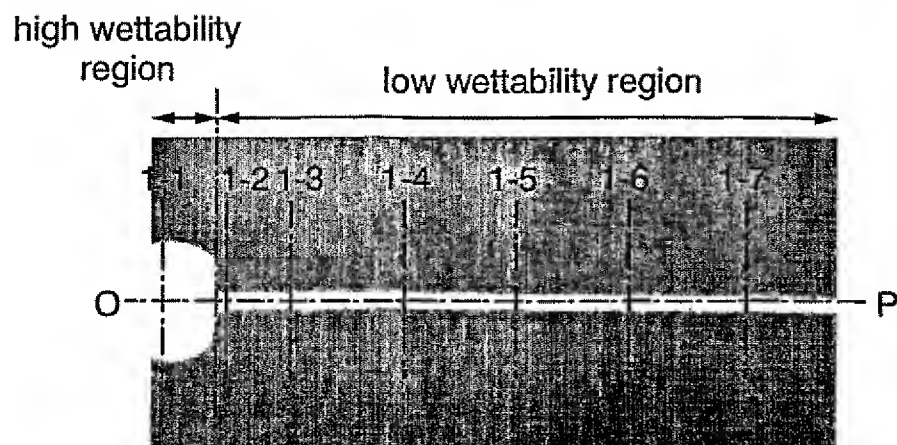


FIG. 42A



FIG. 42B

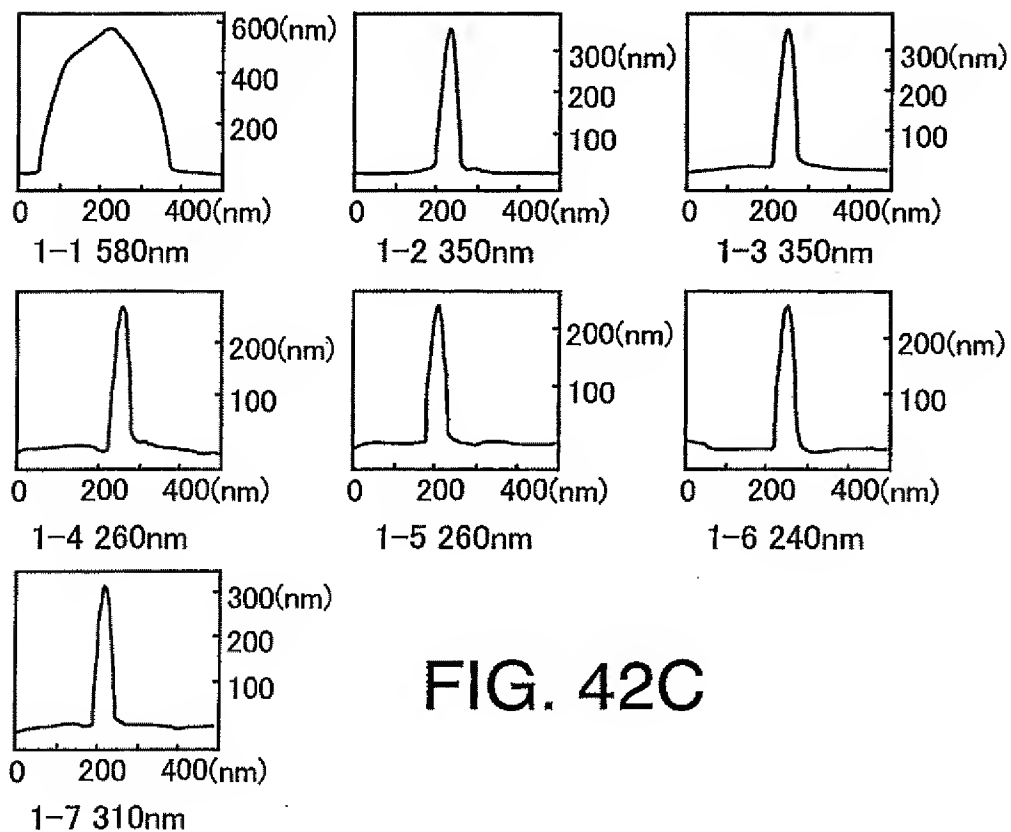


FIG. 42C

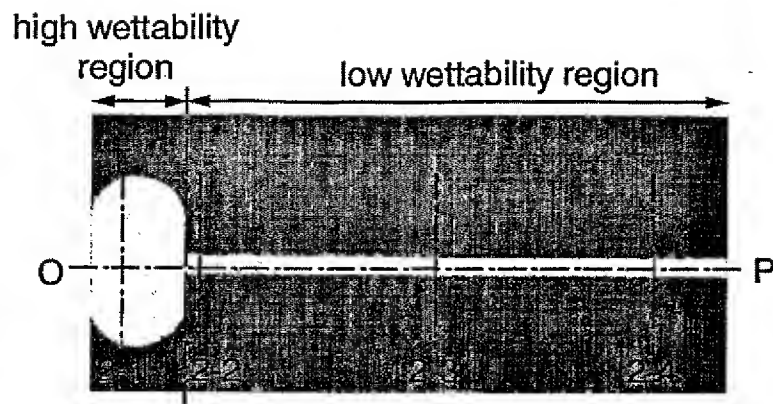


FIG. 43A

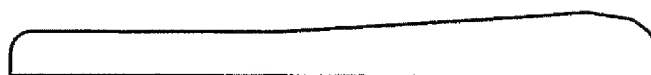


FIG. 43B

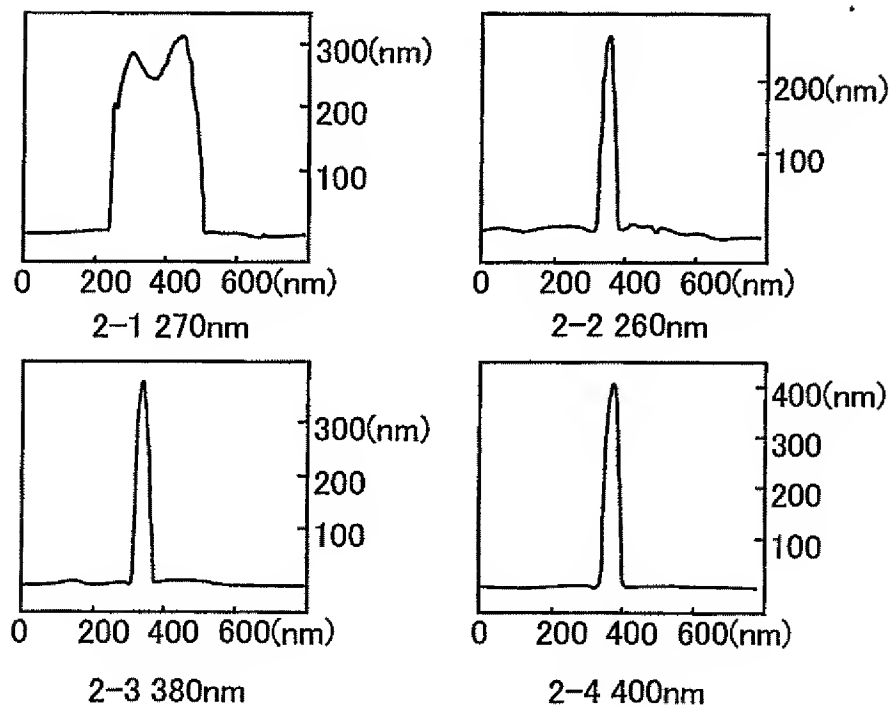


FIG. 43C

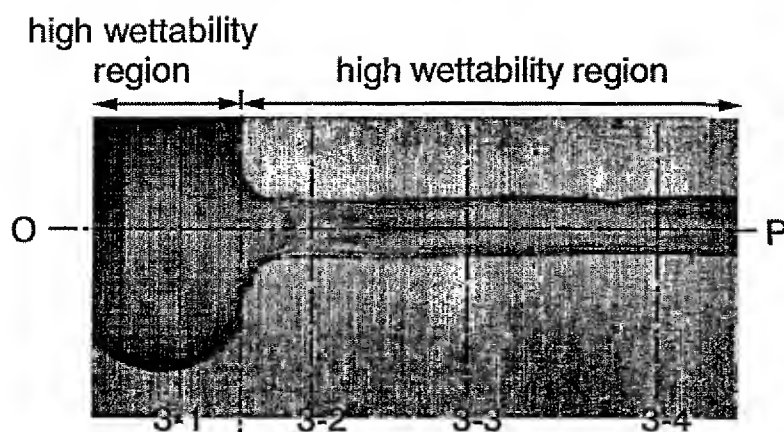


FIG. 44A



FIG. 44B

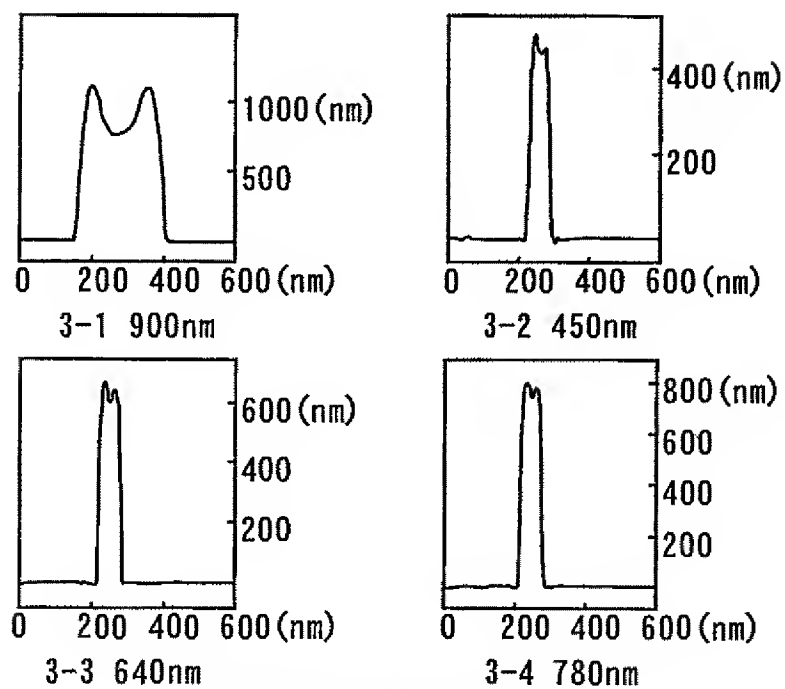


FIG. 44C



## EXPLANATION OF REFERENCE

20: substrate, 30: TFT substrate, 32: sealant, 33: liquid crystal, 34: barrier layer, 35, marker, 40: control device, 42: imaging means, 43: head, 45: marker, 50: substrate, 51: mask, 52: substance, 54: nozzle, 55: droplet, 56: pattern, 57: pattern, 59: pattern, 60: nozzle, 61: droplet, 62: pattern, 63: pattern, 70: substrate, 71a: mask, 71b: mask, 71c: mask, 72: substance, 76: pattern, 77: pattern, 100: substrate, 101: mask, 103: gate electrode layer, 104: gate electrode layer, 105: gate electrode layer, 106: gate electrode layer, 107: semiconductor layer, 108: semiconductor layer, 109: n-type semiconductor layer, 110: n-type semiconductor layer, 111: drain electrode layer, 112: drain electrode layer, 113: drain electrode layer, 114: drain electrode layer, 116: gate insulating layer, 117: electrode layer, 121: insulating layer, 122: electroluminescent layer, 123: electrode layer, 125: mask, 126: high wettability region, 127: gate electrode layer, 145: contact hole, 160: connecting wiring layer, 161: connecting wiring layer, 162: connecting wiring layer, 163: connecting wiring layer, 180a: nozzle, 180b: nozzle, 301: low wettability region, 303: gate electrode layer, 305: gate insulating layer, 307: n-type semiconductor layer, 308: drain electrode layer, 311: pixel electrode layer, 312: insulating layer, 320: liquid crystal layer, 321: insulating layer, 322: colored layer, 323: conductive layer, 324: opposing substrate, 325: polarizing plate, 330: drain electrode layer, 345: contact hole, 350: pattern, 351: substance, 360: low wettability substance, 380: nozzle, 381: nozzle, 401: TFT, 402: capacitor element, 403: TFT, 404: TFT, 405: light-emitting element, 406: TFT, 410 signal line,

411: power source line, 412: power source line, 413: power source line, 414: scanning line, 415: power source line, 416: scanning line, 441: switching TFT, 442: capacitor element, 443: driver TFT, 444: light-emitting element, 445: TFT, 450: signal line, 451: power source line, 452: power source line, 453: scanning line, 454: scanning line, 462: drain electrode, 463: electrode, 464: electroluminescent layer, 465: electrode, 471: drain electrode, 472: electrode, 473: electroluminescent layer, 474: electrode, 480: substrate, 481: thin film transistor, 484: electrode, 485: electroluminescent layer, 486: electrode, 500: block, 501: TFT, 502: TFT, 503: light-emitting element, 504: capacitor element, 505: drain wiring layer, 554: common electric potential line, 555: common electric potential line, 556: common electric potential line, 557: common electric potential line, 561: protective diode, 562: protective diode, 563: protective diode, 564: protective diode, 601: TFT, 620: TFT, 901: buffer circuit, 902: pixel, 1400: substrate, 1403: droplet discharging means, 1404: imaging means, 1405: head, 1406: dotted line, 1407: controlling means, 1408: recording medium, 1409: image processing means, 1410: computer, 1411: marker, 1412: head, 1413: material supply source, 1414: material supply source, 2001: housing, 2002: display panel, 2003: main screen, 2004: modem, 2005: receiver, 2006: remote control device, 2007: display portion, 2008: sub screen, 2009: speaker portion, 2101: main body, 2102: housing, 2103: display portion, 2104: key board, 2105: external connecting port, 2106: pointing mouse, 2201: housing, 2203: display portion A, 2204: display portion B, 2206: operation key, 2207: speaker portion, 2301: main body, 2302: audio output portion, 2303: audio input portion, 2304: display

portion, 2305: operation switch, 2306: antenna, 2401: main body, 2402: display portion, 2405: remote control receiving portion, 2406: image receiving portion, 2407: battery, 2408: audio input portion, 2409: operation key, 2410: eye contact portion, 2600: TFT substrate, 2601: opposing substrate, 2602: sealant, 2603: pixel portion, 2604: liquid crystal layer, 2605: colored layer, 2606: polarizing plate, 2607: polarizing plate, 2608: driver circuit, 2609: flexible wiring substrate, 2610: cold-cathode tube, 2611: reflecting plate, 2612: circuit substrate, 2613: lens film, 2700: substrate, 2701: pixel portion, 2702: pixel, 2703: scanning line side input terminal, 2704: signal line side input terminal, 2750: FPC, 2751: driver IC, 2800: TFT substrate, 2801: protective circuit portion, 2802: TFT, 2803: TFT, 2804: light-emitting element, 2805: light-emitting element, 2806a: spacer, 2806b: spacer, 2807a: colored layer, 2807b: colored layer, 2807c: colored layer, 2809: external circuit, 2810: wiring substrate, 2811: circuit substrate, 2812: radiator plate, 2813: heat pipe, 2820: sealing substrate, 3300: device substrate, 3301: pixel portion, 3302: pixel, 3303: sealant, 3305: drying agent, 3307: filler, 3308: source wiring layer, 3310: sealing substrate, 3350: FPC, 3601: antireflection film, 3602: polarizing plate, 3603: retardation film, 3604: retardation film, 3604a: drying agent, 3604b: drying agent, 3605: insulating layer, 3306a: gate wiring layer, 3306b: gate wiring layer, 3700: substrate, 3701: pixel portion, 3702: scanning line side driver circuit, 3704: signal line side input terminal, 4700: substrate, 4701: pixel portion, 4702: scanning line driver circuit, and 4704: signal line driver circuit.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/002681

## A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl.<sup>7</sup> B05D1/26, H01L21/28, 21/288, 21/3205, 21/336, 29/786

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl.<sup>7</sup> B05D1/26, H01L21/28, 21/288, 21/3205, 21/336, 29/786

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996  
 Published unexamined utility model applications of Japan 1971-2005  
 Registered utility model specifications of Japan 1996-2005  
 Published registered utility model applications of Japan 1994-2005

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 11-207959 A (SEIKO EPSON CORPORATION) 1999.08.03, WHOLE DOCUMENT, FIG. 8	1
Y	WHOLE DOCUMENT, FIG. 8	2-7, 9-12, 16
A.	WHOLE DOCUMENT, FIG. 1-21 (FAMILY: NONE)	8, 13-15, 17-22
Y	JP 2003-59940 A (FUJIFILM PHOTO FILM CO., LTD.) 2003.02.28, WHOLE DOCUMENT, FIGS. 1-4 (FAMILY: NONE)	2-7, 9-12, 16

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"I" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

Date of the actual completion of the international search

19.04.2005

Date of mailing of the international search report

10.05.2005

Name and mailing address of the ISA/JP

Japan Patent Office

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Authorized officer

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4M 2934